THE CITY OF CALGARY
Wastewater & Drainage

STORMWATER MANAGEMENT
&
DESIGN MANUAL

December
2000

Preface

Stormwater management is regulated provincially under both the Environmental Protection and Enhancement Act and the Water Act. Although provincial stormwater guidelines are available, the establishment of this document is an integral part of stormwater management and environmental protection for The City of Calgary. Development of the manual involved the participation of numerous groups and individuals, many of which have a number of years of expertise.

This is the first stormwater management and design manual produced by Wastewater & Drainage and will be updated on a regular basis as standards, designs, and regulatory requirements change or evolve. While the goal of this document is to provide a comprehensive design manual that results in effective, reliable, and economically affordable systems, it is not meant to stifle technological innovation and evolution. Flexibility is important for site specific conditions. Alternative approaches may be considered if it can be demonstrated that there are better ways of achieving the same objectives. The designer is still responsible for detailed design and satisfactory operation and performance.

There is some limited experience with stormwater techniques and designs in Alberta, and in Calgary, particularly when it comes to wetland design, best management practices and the affect of chinooks on design. While this should not discourage use of new technologies, there must be regard for monitoring performance. Ongoing maintenance is extremely important to ensure continued effectiveness.

104-02885/

Acknowledgements

Wastewater & Drainage gratefully acknowledges the guidance and direction involved by members in the advisory and workshop groups in developing this document. Countless hours were spent attending workshops and reviewing documents. Thank you to the following people:

Wastewater & Drainage

Bellmont, Dave
Bouchard, Paul
Bowerman, Al
Bozic, Liliana
Brick, Bob
Broda, Barry
Colborne, Bruce
Davenport, Dan
Deong, Yin
Fedick, Terry
Kennedy, Neil
Knudtson, Eric
Letourneau, Rene
Lyon, Christy
MacIsaac, Mike
McAuley, Jim
Narvaez, Luis
Prince, Terry
Sharp, Jennifer
Shaughnessy, Ken
Shustack, Lidia

Urban Development

Grant, Ted
Norris, Ian
Simmons, Heather
Travis, Dave

Park Development & Operations

Cerveny, Kaja
Elphinstone, Dave
Kenny, Michael
Manderson, Chris
Ripley, Kyle
Ziriada, Peter

Building Regulations

Amin, Tariq
Price, David

Alberta Environment

Lazorko-Connon, Suzanne
Rush, Brock

River Valleys Committee

Amell, Bernie
Morrison, Bill

Consultants (UDI Representatives)

Carnduff, Rick	Stantec Consulting Ltd.
Fitzgerald, Robin	Reid Crowther & Partners Ltd./Klohn-Crippen Consultants Ltd.
Hobbs, Curtis	Sunbow Consulting Ltd.
MacKenzie, John	Operational Solutions

Nolan, Ron	Urban Development Institute
Parent, Ted	Progressive Engineering Ltd.
Pasquini, Tony	Sunbow Consulting Ltd.
Sinden, Ron	Stantec Consulting Ltd.
Spring, Carol	Progressive Engineering Ltd.
van Duin, Bert	Agra Earth & Environ. Ltd./ Westhoff Engineering Resources Inc.
Westhoff, Dennis	Westhoff Engineering Resources Inc.
Young, Brett	Reid Crowther & Partners Ltd.

Miscellaneous Consultants and Agencies

Brunen, Jerry	Ducks Unlimited
Hayes, Ken	Inland Construction (Road Builders Association)
Lalani, Nazim	McIntosh Lalani Engineering Ltd.
Lim, Kenny	Lim Associates Inc.

Special thanks go to Sylvain Mayer (City of Calgary-ITS Department) for his invaluable time and assistance in formatting and assembling the document. Without his help, the document wouldn't look as good as it does. A big thank you also goes to Sewer Drafting and Cliff Brady for their help in preparing some of the figures.

Kim Jaska, M.Eng., P.Eng.
Stormwater Guidelines Engineer (Author)
Wastewater & Drainage

Ordering

Copies of this document may be obtained by:

(1) City of Calgary
Planning & Transportation Policy #8108
Information Centre (Document Sales)-4th floor
800 Macleod Trail SE
(403)268-5333
Fax: (403)268-4615

(2) City of Calgary
Engineering Services #8026
Building Grades Counter-6th floor
800 Macleod Trail SE
(403)268-5703

(3) Web Site: www.gov.calgary.ab.ca

Table of Contents

Page

1.0 Stormwater Management and Planning 1-1
1.1 General-Principles, Policies and Objectives 1-1
1.2 Dual Drainage Concept 1-2
1.2.1 Minor System 1-2
1.2.2 Major System 1-3
1.3 Level of Service 1-4
1.4 Planning Levels 1-4
1.4.1 Introduction 1-4
1.4.2 River Basin Plan (RBP) 1-7
1.4.3 Watershed Plan (WP) 1-7
1.4.4 Master Drainage Plan (MDP) 1-7
1.4.5 Staged Master Drainage Plan (SMDP) 1-8
1.4.6 Subdivision Report (SWMR) 1-9
1.4.7 Drainage & Site Servicing Plan (DSSP) 1-9
1.4.8 Special Projects and Contracts (SP) 1-9
1.4.9 Biophysical Impact Assessment (BIA) 1-10

2.0 Approvals & Processes 2-1
2.1 General 2-1
2.2 Federal 2-1
2.2.1 Navigable Waters Protection Act 2-1
2.2.2 Fisheries Act 2-1
2.3 Province of Alberta 2-2
2.3.1 Environmental Protection and Enhancement Act 2-2
2.3.2 Wastewater and Storm Drainage Regulation (Alberta Regulation 119/93) 2-2
2.3.3 Water Act 2-3
2.3.3.1 Dam and Canal Safety 2-3
2.3.4 Calgary Restricted Development Area Regulation 2-3
2.3.5 Public Lands Act 2-4
2.3.6 Stormwater Reports 2-4
2.4 City of Calgary 2-4
2.4.1 Wastewater & Drainage 2-4
2.4.2 Park Development & Operations 2-7
2.4.3 River Valleys Committee 2-7
2.4.4 Bow River Basin Council 2-8

3.0 Stormwater Design 3-1
3.1 Drainage System 3-1
3.1.1 Policy, Goals and Objectives 3-1
3.1.2 Minor System 3-1
3.1.2.1 General Requirements 3-2
3.1.2.2 Level of Service 3-2
3.1.2.3 Unit Area Release Rate Method 3-3
3.1.2.4 Modified Unit Area Release Rate Method 3-4
3.1.2.5 Rational Method 3-5
3.1.3 Major System 3-7
3.1.3.1 General Requirements 3-7
3.1.3.2 Level of Service 3-7
3.2 Runoff Analysis 3-8
3.2.1 General 3-8
3.2.2 Computer Models 3-8

3.2.2.1 General 3-8
3.2.2.2 OTTHYMO/INTERHYMO 3-9
3.2.2.3 SWMHYMO 3-9
3.2.2.4 SWMM 3-10
3.2.2.5 OTTSWMM 3-11
3.2.2.6 DDSWMM 3-11
3.2.2.7 XP-SWMM 3-12
3.2.2.8 QUALHYMO 3-12
3.2.2.9 QHM 3-12
3.2.2.10 EXTRAN 3-13
3.2.2.11 Other Models 3-13
3.2.2.12 Calibration 3-13
3.2.3 Single Event vs. Continuous 3-13
3.2.4 Design Storm 3-14
3.2.4.1 General 3-14
3.2.4.2 IDF Curve and Parameters 3-14
3.2.4.3 Chicago Distribution 3-17
3.2.4.4 Storm Duration 3-17
3.2.5 Parameters 3-18
3.2.5.1 Runoff Coefficient C 3-18
3.2.5.2 Depression Storage 3-20
3.2.5.3 Infiltration 3-20
3.2.5.3.1 Horton Method 3-20
3.2.5.3.2 Soil Conservation Service (SCS) Method 3-21
3.2.5.4 Curve Number (CN) 3-22
3.2.5.5 Imperviousness 3-23
3.2.6 Statistical Analysis 3-24
3.3 Minor System Component Design 3-24
3.3.1 Design Basis 3-24
3.3.2 Pipes 3-25
3.3.2.1 Design Flow 3-25
3.3.2.2 Capacity & Size 3-25
3.3.2.3 Flow Velocities and Minimum Slope 3-26
3.3.2.4 Cover 3-27
3.3.2.5 Pipe Material, Strength & Bedding 3-27
3.3.2.6 Concrete Encasement 3-28
3.3.2.7 Drainage Length 3-28
3.3.2.8 Curved Sewers 3-29
3.3.2.9 Oversize 3-29
3.3.2.10 Hydraulics 3-29
3.3.2.11 Alignment & Easements 3-29
3.3.3 Manholes 3-30
3.3.3.1 Location 3-30
3.3.3.2 Types 3-30
3.3.3.3 Material 3-30
3.3.3.4 Spacing 3-31
3.3.3.5 Drops 3-31
3.3.3.6 Benching 3-31
3.3.3.7 Junctions and Bends 3-31
3.3.3.8 Hydraulics 3-32
3.3.3.9 Service Connections 3-32
3.3.4 Catchbasins 3-32
3.3.4.1 Location 3-32
3.3.4.2 Types 3-32

3.3.4.3 Material 3-33
3.3.4.4 Capacity 3-33
3.3.4.5 Spacing 3-35
3.3.4.6 Lead Sizes & Slopes 3-36
3.3.4.7 Hydraulics 3-36
3.3.5 Inlet Control Devices 3-36
3.3.5.1 Types 3-36
3.3.5.2 Discharge 3-37
3.3.6 Weeping Tile (Foundation Drain) 3-38
3.3.6.1 Types 3-38
3.3.6.2 Requirements 3-39
3.3.6.3 Size & Slope 3-40
3.3.6.4 Cover 3-40
3.3.6.5 Backwater Valves 3-40
3.3.6.6 Hydraulics 3-40
3.3.6.7 Service Connections 3-41
3.3.6.8 Water Table Requirements 3-41
3.3.7 Outfalls 3-42
3.3.7.1 General 3-42
3.3.7.2 Hydraulics 3-43
3.3.7.3 Maintenance 3-43
3.3.7.4 Safety & Aesthetics 3-43
3.3.8 Culverts 3-44
3.3.9 Pumping 3-44
3.4 Major System Component Design 3-44
3.4.1 Roof Leaders 3-44
3.4.2 Lot Grading & Drainage 3-44
3.4.2.1 Types 3-44
3.4.2.2 Requirements 3-45
3.4.2.3 MGs/RMGs/TOSs/Restrictive Covenants 3-45
3.4.3 Roads 3-46
3.4.4 Trap Lows (Surface Ponding) 3-48
3.4.4.1 Requirements 3-48
3.4.4.2 Manhole Seals 3-49
3.4.5 Roof Top Storage 3-50
3.4.6 Swales 3-50
3.4.6.1 Grass 3-50
3.4.6.2 Concrete 3-50
3.4.7 Escape Routes 3-52
3.4.8 Receiving Waters 3-52
3.4.9 Outfall Channels 3-53
3.4.10 Stormwater Ponds 3-53
3.5 Floodplain Requirements 3-53
3.6 Technical Requirements 3-54

4.0 Drainage & Site Servicing Plans (Commercial/Industrial/Multi-Family) 4-1

4.1 General 4-1
4.2 Minor System 4-1
4.2.1 General Requirements 4-1
4.2.2 Level of Service 4-2
4.2.2.1 Unit Area Release Rate Method 4-2
4.2.2.2 Modified Unit Area Release Rate Method 4-2
4.2.2.3 Rational Method 4-3
4.3 Major System 4-3

4.3.1 General ... 4-3
4.3.2 Level of Service ... 4-4
4.4 Minor System Component Design ... 4-4
4.4.1 Service Connections ... 4-4
4.4.1.2 Servicing ... 4-5
4.4.1.3 Location ... 4-5
4.4.1.4 Grades ... 4-5
4.4.1.5 Manholes ... 4-6
4.5 Major System Component Design ... 4-6
4.6 Servicing ... 4-6
4.6.1 Serviced Sites ... 4-6
4.6.2 Non-Serviced Sites ... 4-7
4.7 Storage Requirements & Methods ... 4-8
4.7.1 Manual Calculations/Graphs ... 4-8
4.7.1.1 Rational Method ... 4-8
4.7.1.2 Unit Area Release Rate Method ... 4-8
4.7.2 Computer Modelling ... 4-9
4.8 Storage Options ... 4-9
4.8.1 Parking Lot Storage (trap lows) ... 4-10
4.8.2 Roof Top Storage ... 4-10
4.8.3 Dry Wells ... 4-10
4.8.4 Underground ... 4-10
4.8.5 Stormwater Ponds ... 4-11
4.8.6 Evaporation Ponds ... 4-11
4.8.7 Pond Approvals ... 4-13
4.9 Hydraulics ... 4-13
4.10 Lot Grading & Drainage ... 4-14
4.11 Water Quality ... 4-14
4.12 Best Management Practices ... 4-14
4.13 Erosion & Sediment Control ... 4-15
4.14 Technical Requirements ... 4-16

5.0 Hydraulic Design ... 5-1
5.1 Need for Hydraulic Considerations ... 5-1
5.2 General ... 5-1
5.3 Energy Losses ... 5-2
5.3.1 Pipe Friction Losses ... 5-3
5.3.2 Form Losses ... 5-3
5.4 Special Structures ... 5-12
5.5 Stage-Discharge Curves ... 5-12
5.6 Technical Requirements ... 5-14
5.6.1 Submission ... 5-14
5.6.2 Design ... 5-15

6.0 Stormwater Ponds ... 6-1
6.1 General ... 6-1
6.1.1 Terminology ... 6-1
6.1.2 Level of Service ... 6-3
6.1.3 Overland Drainage Routes ... 6-4
6.1.4 Vegetation Use ... 6-4
6.1.5 Water Quality ... 6-5
6.1.6 Geotechnical ... 6-5
6.1.7 Signage ... 6-6
6.1.8 Operating and Maintenance Manual ... 6-6

6.1.9 Monitoring System 6-6
  6.1.9.1 Equipment......6-7
  6.1.9.2 Setup and Calibration......6-8
  6.1.9.3 Alarms......6-9
6.1.10 Maintenance Periods......6-9
  6.1.10.1 Staged Construction......6-9
  6.1.10.2 Dry Ponds & Wet Ponds 6-9
  6.1.10.3 Wetlands......6-10
  6.1.10.4 Automatic Control Gates 6-11
6.2 Dry Ponds 6-11
6.2.1 Introduction 6-11
6.2.2 Design......6-12
  6.2.2.1 Level of Service/Volumetric Sizing 6-13
  6.2.2.2 Land Dedication 6-14
  6.2.2.3 Frequency of Inundation 6-14
  6.2.2.4 Drainage Area......6-15
  6.2.2.5 Pond Area & Number of Ponds 6-15
  6.2.2.6 Winter Operation......6-15
  6.2.2.7 Sediment Forebay......6-15
  6.2.2.8 Forebay Berm 6-16
  6.2.2.9 Detention Time......6-16
  6.2.2.10 Length:Width Ratio......6-16
  6.2.2.11 Pond Depth......6-17
  6.2.2.12 Overland Drainage Routes......6-17
  6.2.2.13 Hydraulics 6-17
  6.2.2.14 Landscaping & Vegetation 6-18
  6.2.2.15 Grading/Slopes 6-20
  6.2.2.16 Subdrainage System......6-20
  6.2.2.17 Inlet(s), Inlet/Outlet(s) & Catchbasins......6-21
  6.2.2.18 Outlet Control Structure 6-23
  6.2.2.19 Maintenance Vehicle Access 6-24
  6.2.2.20 Fencing......6-25
  6.2.2.21 Monitoring System 6-25
  6.2.2.22 Signage......6-25
  6.2.2.23 Enhancements......6-26
6.3 Wet Ponds......6-26
6.3.1 Introduction 6-26
6.3.2 Design......6-27
  6.3.2.1 Level of Service/Volumetric Sizing 6-29
  6.3.2.2 Land Dedication......6-29
  6.3.2.3 Drainage Area......6-30
  6.3.2.4 Pond Area & Number of Ponds 6-30
  6.3.2.5 Winter Operation......6-30
  6.3.2.6 Circulation......6-30
  6.3.2.7 Water Quality 6-31
  6.3.2.8 Sediment Forebay......6-31
  6.3.2.9 Forebay Berm 6-34
  6.3.2.10 Detention Time......6-35
  6.3.2.11 Length:Width Ratio......6-35
  6.3.2.12 Pond Depth......6-36
  6.3.2.13 Overland Drainage Routes......6-36
  6.3.2.14 Hydraulics 6-37
  6.3.2.15 Landscaping & Vegetation 6-37
  6.3.2.16 Pond Edge Treatment......6-40

6.3.2.17 Recreational Activities 6-40
6.3.2.18 Grading/Slopes 6-41
6.3.2.19 Geotechnical 6-42
6.3.2.20 Inlet(s) 6-42
6.3.2.21 Outlet Control Structure 6-44
6.3.2.22 Maintenance Vehicle Access 6-46
6.3.2.23 Fencing 6-46
6.3.2.24 Monitoring System 6-46
6.3.2.25 Signage 6-47
6.3.2.26 Public Education 6-47
6.3.2.27 Enhancements 6-48
6.4 Wetlands 6-48
6.4.1 Introduction 6-48
6.4.2 Design 6-53
6.4.2.1 Overall Design Philosophy 6-54
6.4.2.2 Level of Service/Volumetric Sizing 6-55
6.4.2.3 Land Dedication 6-56
6.4.2.4 Drainage Area 6-57
6.4.2.5 Pond Area & Number of Ponds 6-57
6.4.2.6 Winter Operation 6-57
6.4.2.7 Water Quality 6-58
6.4.2.8 Sediment Forebay 6-58
6.4.2.9 Forebay Berm 6-59
6.4.2.10 Detention Time 6-60
6.4.2.11 Length:Width Ratio 6-60
6.4.2.12 Pond Depth 6-61
6.4.2.13 Overland Drainage Routes 6-61
6.4.2.14 Hydraulics 6-62
6.4.2.15 Landscaping & Vegetation 6-63
6.4.2.16 Recreational Activities 6-63
6.4.2.17 Grading/Slopes 6-64
6.4.2.18 Geotechnical 6-66
6.4.2.19 Inlet(s) 6-66
6.4.2.20 Outlet Control Structure 6-68
6.4.2.21 Maintenance Vehicle Access 6-71
6.4.2.22 Fencing 6-71
6.4.2.23 Monitoring System 6-71
6.4.2.24 Signage 6-72
6.4.2.25 Public Education 6-72
6.4.2.26 Enhancements 6-73

7.0 Water Quality 7-1
7.1 General 7-1
7.2 Declining Water Quality 7-1
7.3 Need for Improved Water Quality 7-4
7.4 Regulatory Requirements 7-5
7.4.1 Present 7-5
7.4.2 Future 7-5
7.5 Water Quality Modelling 7-6
7.5.1 Objective 7-6
7.5.2 Urban Runoff Water Quality Models 7-6
7.5.2.1 SWMM 7-7
7.5.2.2 QUALHYMO 7-7
7.5.2.3 QHM 7-8

7.5.2.4 Others 7-8
7.5.3 Modelling Criteria 7-8
7.5.3.1 Continuous Simulation 7-8
7.5.3.2 Particle Sizes and Settling Velocities 7-9
7.5.3.3 Rate of Sediment Accumulation 7-10
7.5.3.4 Technical Requirements 7-10
7.6 Pond Sizing 7-10
7.7 Cold Climate Impacts 7-10
7.8 Water Quality Monitoring Program 7-11

8.0 Best Management Practices 8-1
8.1 Introduction 8-1
8.2 Source Control BMPs 8-2
8.2.1 Pesticide and Fertilizer Use 8-2
8.2.2 Good Housekeeping 8-3
8.2.3 Household, Industrial and Commercial Activities 8-4
8.2.4 Automobile-related Activities 8-4
8.2.5 Construction Activities 8-5
8.2.6 Street Sweeping 8-5
8.2.7 Catchbasin Cleaning 8-5
8.2.8 Animal Waste Removal 8-6
8.3 Lot-Level BMPs 8-6
8.3.1 Reduced Lot Grading 8-6
8.3.2 Surface Ponding and Roof Top Storage 8-7
8.3.3 On-Lot Infiltration Systems 8-8
8.3.4 Sump Pumping of Foundation/Weeping Tile Drains 8-10
8.3.5 Superpipe Storage 8-11
8.3.6 Infiltration Trenches 8-11
8.4 Conveyance System BMPs 8-13
8.4.1 Pervious Pipe Systems 8-13
8.4.2 Pervious Catchbasins 8-15
8.4.3 Grassed Swales 8-16
8.5 Treatment BMPs 8-17
8.5.1 Dry Ponds 8-18
8.5.2 Wet Ponds 8-18
8.5.3 Wetlands 8-19
8.5.4 Infiltration Basins 8-19
8.5.5 Filters 8-21
8.6 Pre-treatment and Special Purpose BMPs 8-23
8.6.1 Filter Strips 8-23
8.6.2 Buffer Strips 8-24
8.6.3 Oil/Grit Separators 8-24
8.6.4 Porous Pavement 8-26
8.7 BMP Screening and Selection 8-27
8.7.1 Physical Site Constraints 8-27
8.7.2 Initial Screening 8-30
8.7.3 Final Screening 8-31
8.8 Cold Climate Impacts 8-32
8.9 Operation and Maintenance 8-33

9.0 Erosion & Sediment Control 9-1
9.1 Introduction 9-1
9.1.1 Erosion & Sedimentation Process 9-2
9.1.1.1 Types of Erosion 9-3

9.1.1.2 Factors Influencing Erosion 9-4
9.1.2 Goals & Objectives 9-6
9.1.3 Applicable Design Documents 9-7
9.1.4 Regulatory Requirements 9-7
9.1.4.1 Federal 9-7
9.1.4.2 Provincial 9-8
9.1.4.3 Municipal 9-10
9.1.5 Responsibilities 9-11
9.2 Planning 9-12
9.3 Design Approach 9-14
9.4 Methods 9-17
9.4.1 Good Housekeeping Practices 9-18
9.4.2 Erosion Control 9-19
9.4.2.1 Protection of Exposed Surfaces 9-21
9.4.2.2 Control of Runoff 9-23
9.4.3 Sediment Control 9-25
9.4.3.1 Filtering 9-25
9.4.3.2 Impoundments 9-29
9.5 Temporary Measures vs Permanent Measures 9-31
9.6 Monitoring and Maintenance 9-32
9.6.1 Inspections 9-32
9.6.2 Maintenance and Repairs 9-33
9.6.3 Records 9-33
9.7 Technical Requirements 9-33
9.7.1 Reports 9-33
9.7.1.1 Subdivision 9-35
9.7.1.2 Drainage & Site Servicing Plan 9-35
9.7.1.3 Maintenance and Repairs 9-35
9.7.2 Construction Drawings 9-36

10.0 Operating, Maintenance and Monitoring Requirements 10-1

10.1 General 10-1
10.1.1 History 10-1
10.1.2 Need for Maintenance 10-1
10.1.3 Responsibilities 10-2
10.1.4 Inspections 10-2
10.1.5 Contacts 10-3
10.1.6 Equipment Access 10-3
10.2 Operation and Maintenance Activities 10-3
10.2.1 Minor System 10-3
10.2.2 Stormwater Ponds 10-4
10.2.2.1 General 10-4
10.2.2.2 Control of Hazardous Spills and Chemical Treatment 10-4
10.2.2.3 Turf & Landscaping 10-5
10.2.2.4 Debris Removal and Vandalism 10-5
10.2.2.5 Control of Weeds, Aquatic Weeds and Algae 10-6
10.2.2.6 Vegetation and Harvesting 10-7
10.2.2.7 Mosquito Control 10-8
10.2.2.8 Odour Control 10-8
10.2.2.9 Aeration and Circulation 10-8
10.2.2.10 Makeup Water 10-9
10.2.2.11 Sediment Removal and Disposal 10-9
10.2.2.12 Signage 10-10
10.2.2.13 Structures 10-11

10.2.2.14 Winter Activities ... 10-12
10.2.2.15 Winter Operation ... 10-12
10.2.3 Other Best Management Practices ... 10-12
10.2.3.1 Filtration System (Soakaway Pits) ... 10-15
10.2.3.2 Infiltration Trenches ... 10-15
10.2.3.3 Pervious Pipe System ... 10-16
10.2.3.4 Pervious Catchbasins ... 10-16
10.2.3.5 Grassed Swales ... 10-16
10.2.3.6 Infiltration Basins ... 10-16
10.2.3.7 Filters ... 10-17
10.2.3.8 Filter Strips ... 10-17
10.2.3.9 Buffer Strips ... 10-17
10.2.3.10 Oil/Grit Separators ... 10-17
10.2.4 Pumping Facilities ... 10-18
10.2.5 Monitoring Requirements ... 10-18
10.2.5.1 Water Level and Water Quality ... 10-18
10.2.5.2 Annual Maintenance and Checks ... 10-18
10.2.6 Operating and Maintenance Manual ... 10-19
10.2.7 Capital and Operating Costs ... 10-19

11.0 Technical Requirements ... 11-1

11.1 Reports ... 11-1
11.1.1 River Basin Plan (RBP) ... 11-1
11.1.2 Watershed Plan (WP) ... 11-1
11.1.3 Master Drainage Plan (MDP) ... 11-1
11.1.3.1 Submission & Technical Requirements ... 11-2
11.1.4 Staged MDP (SMDP) ... 11-2
11.1.4.1 Submission Requirements ... 11-3
11.1.4.2 Technical Requirements ... 11-3
11.1.5 Subdivision (SWMR) ... 11-5
11.1.5.1 Submission Requirements ... 11-5
11.1.5.2 Technical Requirements ... 11-6
11.1.6 Stormwater Ponds ... 11-10
11.1.6.1 Submission Requirements ... 11-10
11.1.6.2 Technical Requirements ... 11-11
11.1.7 Drainage & Site Servicing Plans (DSSP) ... 11-12
11.1.7.1 Submission and Technical Requirements ... 11-12
11.1.8 Special Projects and Contracts (SP) ... 11-13
11.1.8.1 Submissions and Technical Requirements ... 11-13
11.1.9 Biophysical Impact Assessment ... 11-13
11.1.9.1 Submission Requirements ... 11-13
11.1.9.2 Technical Requirements ... 11-15
11.1.10 Report Re-Submissions ... 11-17
11.2 Engineering Drawings ... 11-17
11.2.1 Subdivision ... 11-17
11.2.1.1 Preliminary, Final, and Revised Finals ... 11-17
11.2.1.2 Drawing Requirements ... 11-18
11.2.2 Stormwater Ponds ... 11-21
11.2.2.1 Drawing Requirements ... 11-21
11.2.3 Drainage & Site Servicing Plans (DSSPs) ... 11-23
11.2.3.1 Drawing Requirements ... 11-23
11.2.4 Special Projects and Contracts (SP) ... 11-24
11.2.4.1 Drawing Requirements ... 11-24
11.3 Inspections ... 11-24

11.4 Certificates 11-24
11.5 As-Builts 11-25
  11.5.1 Purpose 11-25
  11.5.2 Subdivision 11-25
  11.5.3 Ponds 11-26
  11.5.4 Drainage & Site Servicing Plans 11-26

12.0 References 12-1

Appendix A Process for Application and Approval for Stormwater Ponds and Outfalls (EPEA) A-1
Appendix B Storm Retention Calculations for Drainage & Site Servicing Plans B-1
Appendix C Monitoring Equipment for Ponds C-1
Appendix D Signage for Ponds D-1
Appendix E Recommended Plant Species E-1
Appendix F Wetland Designs Comparison F-1
Appendix G Source Control BMPs G-1
Appendix H Minimum Requirements for Erosion & Sediment Control Reports H-1
Appendix I Maintenance and Response Procedures for Stormwater Ponds (Wastewater & Drainage) I-1
Appendix J Stormwater Pond Check Sheets J-1

List of Figures

Page

Figure 1.1: Major & Minor Systems 1-2
Figure 1.2: Minor System Components 1-3
Figure 1.3: Stormwater Management Planning 1-5
Figure 2.1: Subdivision and Pond Approvals Process-Coordination with Alberta Environment 2-5
Figure 3.1: Unit Area Release Rate vs. On-Site Storage 3-4
Figure 3.2: Storm Sewer Design Curve for Rational Method 3-6
Figure 3.3: MSC IDF Curve for Calgary 3-15
Figure 3.4: Horton Infiltration Curve using Alberta Soils and Recommended Values 3-21
Figure 3.5: Capture Rating Curve for City of Calgary Catchbasins under Flow-by Conditions 3-34
Figure 3.6: Capture Rating Curves for City of Calgary Catchbasins under Ponding Conditions 3-35
Figure 3.7: Capture Rating Curves for Standard City of Calgary Inlet Control Devices 3-37
Figure 3.8: Groundwater Adjustments 3-42
Figure 3.9: Permissible Depths and Velocities 3-47
Figure 3.10: Trap Low Definition 3-49
Figure 4.1: Required Storage vs Imperviousness for Unit Area Release Rate Method 4-9
Figure 4.2: 100 Year Evaporation Pond Volumes for DSSPs 4-12
Figure 5.1: Energy in Closed Conduit (pipe) and Open Channel 5-2
Figure 5.2: Typical K_e and K_c Values for Non-Pressure Flow 5-5
Figure 5.3: Manhole Configurations 5-8
Figure 5.4: Losses Due to Turbulence at Manholes 5-9
Figure 5.5: Head Loss Coefficient Values for Benching 5-10
Figure 5.6: Values of K_b for Bends and Radiuses (AISI 1985) 5-11
Figure 6.1: Dry Pond with Forebay 6-12
Figure 6.2: Low Flow Channel 6-15
Figure 6.3: Dry Pond Slopes 6-20
Figure 6.4: Typical CB Grating 6-22
Figure 6.5: Wet Pond 6-27
Figure 6.6: Forebay for Wet Pond 6-32
Figure 6.7: Extending the Flow Path 6-35
Figure 6.8: Side Slopes for Wet Ponds 6-41
Figure 6.9: Submerged Inlet 6-43
Figure 6.10: Shallow Marsh System (Schueler, 1992) 6-49
Figure 6.11: Pond-Wetland System (Schueler, 1992) 6-50
Figure 6.12: Extended Detention Wetland (Schueler, 1992) 6-51
Figure 6.13: Pocket Wetland (Schueler, 1992) 6-52
Figure 6.14: Extending Flow Path through a Wetland 6-60
Figure 6.15: Typical Side Slopes for Wetlands 6-65
Figure 6.16: Terraced Side Slopes for Wetlands 6-65
Figure 6.17: Unsubmerged Inlet 6-67
Figure 6.18: Reversed Slope Pipe Outlet 6-69
Figure 7.1: Effects of Pollutants on Aquatic Habitat 7-1
Figure 8.1: Lot Grading Guidelines 8-6
Figure 8.2: Rear Yard Ponding 8-7
Figure 8.3: Infiltration System with Roof Leader Filter (Soakaway Pit) 8-8
Figure 8.4: Infiltration System with Pre-treatment Sump 8-9
Figure 8.5: Sump Pump Foundation Drainage 8-10
Figure 8.6: Surface Infiltration Trench 8-11
Figure 8.7: Subsurface Infiltration Trench 8-12
Figure 8.8: Pervious Pipe System 8-14
Figure 8.9: Pervious Catchbasin 8-15
Figure 8.10: Grassed Swale 8-16

Figure 8.11: Infiltration Basin.....8-20
Figure 8.12: Sand Filter Cross Section.....8-21
Figure 8.13: Sand-Peat Filter Cross Section.....8-22
Figure 8.14: Grassed and Wooded Filter Strips.....8-23
Figure 8.15: 3 Chamber Oil/Grit Separator.....8-25
Figure 8.16: Bypass Flow Oil/Grit Separator.....8-25
Figure 8.17: Porous Pavement.....8-26
Figure 9.1: Water Balance at Undeveloped and Developed Sites (Schueler, 1987).....9-1
Figure 9.2: Types of Erosion.....9-4
Figure 9.3: Effects of Vegetative Cover on Stormwater Runoff.....9-5
Figure 9.4: Erosion & Sediment Control Plan Development Process.....9-15
Figure 9.5: Example of Erosion and Sediment Control Features.....9-17
Figure 9.6: Grassed Waterways.....9-24
Figure 9.7: Strawbale Filter.....9-27
Figure 9.8: Brush Barrier.....9-28
Figure 9.9: Rock, Strawbale and Silt Fence Check Dams.....9-28
Figure 9.10: Silt Fence.....9-29
Figure 9.11: Sediment Trap/Pond.....9-30
Figure 9.12: Types of Inlet Protection.....9-30
Figure 9.13: Example of Erosion & Sediment Control Plan.....9-34
Figure 11.1: Review Process for BIAs.....11-14

List of Tables

Page
Table 1.1: Planning Process Flow Chart 1-6
Table 3.1: Storm Sewer Design Table..........3-6
Table 3.2: Design Storm Hyetograph (mm) 3-15
Table 3.3: IDF Parameters-Calgary Municipal Airport 3-16
Table 3.4: Adjusted IDF Curve-Intensity Summary (mm/hr) 3-16
Table 3.5: Adjusted IDF Parameters 3-17
Table 3.6: Typical Urban Runoff Coefficients for 5 to 10 year Return Period Storms..........3-19
Table 3.7: Suggested Depression Storage Losses..........3-20
Table 3.8: SCS Curve Numbers for Urban Areas 3-23
Table 3.9: Typical Imperviousness of Urban Catchments..........3-23
Table 3.10: Minimum Pipe Sizes..........3-26
Table 3.11: Capture Rating Data for City of Calgary Catchbasins under Flow-by Conditions 3-34
Table 3.12: Capture Rating Data for City of Calgary Catchbasins under Ponding Conditions 3-35
Table 3.13: Capture Rating Data for Standard City of Calgary Inlet Control Devices..........3-37
Table 3.14: Test Hole Data 3-41
Table 3.15: Permissible Depths for Submerged Objects 3-47
Table 5.1: Values of K_e for Sudden Enlargement in Pipes (AISI 1996)..........5-5
Table 5.2: Values of K_e for Gradual Enlargement in Pipes (AISI 1996)..........5-6
Table 5.3: Values of K_c for Sudden Contraction (AISI 1996)..........5-6
Table 5.4: Values of k_e for Culverts, Outlet Controls, and Full or Partly Full Entrances..........5-7
Table 6.1: Design Summary Guide for Dry Ponds 6-12
Table 6.2: Design Summary Guide for Wet Ponds 6-27
Table 6.3: Design Summary Guide for Wetlands..........6-53
Table 7.1: Typical Pollutant Concentrations Found in Urban Stormwater 7-2
Table 7.2: Particle Size and Settling Velocities for Sediment Removal..........7-9
Table 8.1: Soil Type Restrictions..........8-27
Table 8.2: Physical BMP Constraints 8-29
Table 8.3: BMP Advantages and Disadvantages 8-30
Table 8.4: Potential BMP Opportunities 8-32
Table 8.5: Cold Climate Challenges..........8-33
Table 9.1: Impact of Suspended and Deposited Sediments on the Aquatic Environment..........9-2
Table 9.2: Degree of Erosion and Sediment Control 9-18
Table 9.3: Erosion Control Measures 9-20
Table 9.4: Sediment Control Measures 9-26
Table 10.1: Inspection Routines for Stormwater Facilities 10-13

THE CITY OF CALGARY
STORMWATER MANAGEMENT & DESIGN MANUAL

1.0 Stormwater Management and Planning

1.1 General-Principles, Policies and Objectives

Stormwater management is a comprehensive approach to the planning, design, implementation, and operation of stormwater drainage infrastructure. Through effective stormwater management, drainage systems can be developed that balance the objectives of maximizing drainage efficiency and minimizing adverse environmental impacts. Stormwater runoff can carry pollutants, that have been deposited on land, into nearby rivers, creeks, lakes, ponds, wetlands and groundwater to the point where water quality and aquatic habitat are degraded. Effective stormwater management can reduce or prevent pollution of our watercourses. In this regard, the goal of The City of Calgary is to *"provide excellent and affordable storm sewer systems to protect Calgarians, their property and the environment".* *(Wastewater & Drainage Mission Statement)*

Effective planning is necessary to provide effective stormwater management since there are few drainage systems in inhabited areas that remain in their natural state. Urbanization, or development, results in an increase in impervious ground cover and an increase in the rate of runoff. Rainstorms that at one time would have little or no runoff in rural areas, now produce significant runoff in developed urban areas and can pollute waterways. The increased runoff also results in a corresponding increase in the concentration and types of pollutant loadings due to nutrients, solids, metals, salt, pathogens, pesticides, and hydrocarbons. However, there are a variety of ways to manage stormwater runoff in urban areas for both water quality and quantity control. These can include storage facilities such as wet ponds, dry ponds or wetlands, or other best management practices (BMPs). BMPs can be effective and practical measures to reduce or prevent pollution caused by stormwater. However, stormwater BMPs vary in their ability and effectiveness to treat pollutants. Where possible, source controls are advocated to prevent pollution in the first place.

> ***"The overall goal of stormwater management is to improve water quality and address water quantity problems through the implementation of stormwater controls and practices.*** *"(Bow River Basin Council)*

While this is first and foremost a stormwater management and design manual, other conditions of development may be required that are outside the scope of this document. Please contact Urban Development for further information.

1.2 Dual Drainage Concept

Traditional stormwater drainage systems have typically consisted of an underground network of pipes and associated structures. These systems were designed to transport flows for relatively minor, or low intensity rainstorms, as a matter of convenience. Although this worked well for the smaller rainstorms, it did not work for the larger rainstorms. Since little or no consideration was given to controlling the runoff from larger rainstorm events, numerous flooding problems typically occurred.

The solution to these past problems was to make allowances for these major rainstorm events in the planning and design of new developments. The division of rainstorms into **minor** and **major** events became known as the "**Dual Drainage Concept**". The **minor** system provides a basic level of service by conveying flows from the more common (low intensity, more frequent) rainstorm events as a convenience. The **major** system conveys runoff from the extreme (high intensity, less frequent) rainstorm events that are in excess of what the minor system can handle. Figure 1.1 illustrates the two components of the Dual Drainage Concept. Good planning and design are critical to successful stormwater management. **All new development areas in Calgary shall be designed using the Dual Drainage Concept (minor /major system) to achieve specific levels of service objectives.**

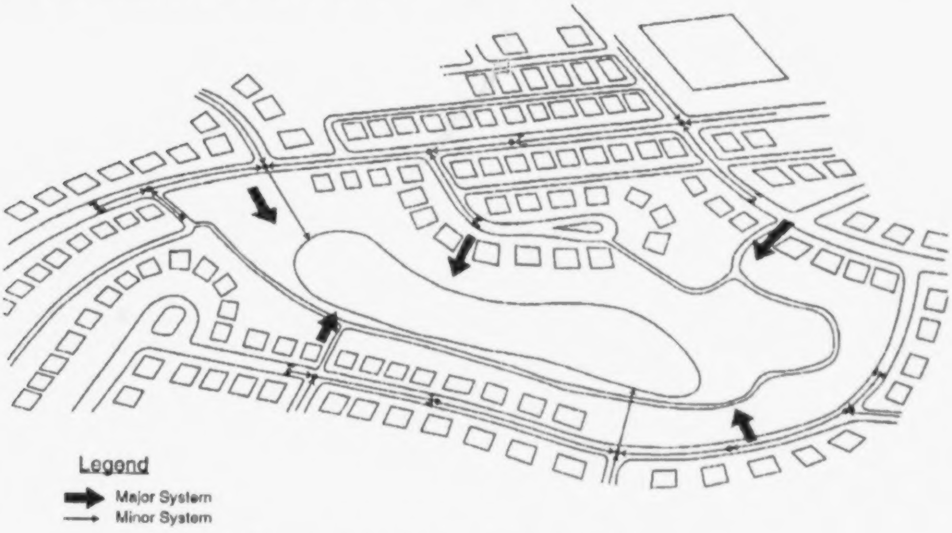


Figure 1.1: Major & Minor Systems

1.2.1 Minor System

The minor stormwater drainage system consists of the underground pipe network and its associated structures. These components facilitate the transport of stormwater flows from minor rainstorms. Components of the minor system typically include:

- Gutters and roof leaders
- Weeping tile
- Lot drainage
- Catchbasins, inlets and leads
- Underground pipe system
- Manholes and junctions
- Outfalls
- Receiving waters

Some components, such as gutters and roof leaders, may be classified under both minor and major system components, since they are considered in the design of each type of system.

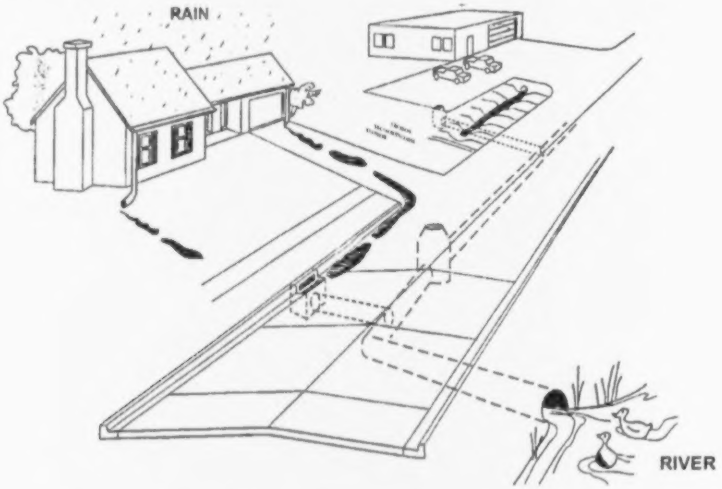


Figure 1.2: Minor System Components

A basic level of service is provided by the minor system. In Calgary, this has typically been sized for the 5 year return period storm since 1952. Prior to 1952, the level of service was based on a 2 year return period storm. With the development of these stormwater guidelines, the minor system will be designed using the unit area release rate method (L/s/ha). In general, the recommended minimum release rate is 70 L/s/ha. Refer to **Section 3.1.2** for more information.

1.2.2 Major System

The major stormwater drainage system conveys runoff from extreme rainfall events that are in excess of the minor underground system. Components of the major system typically include:

- Gutters and roof leaders
- Lot drainage

- Roads
- Swales
- Trap lows
- Escape routes
- Storage facilities (stormwater ponds)
- Outfalls
- Receiving waters

Some components, such as gutters and roof leaders, may be classified under both minor and major system components, since they are considered in the design of each type of system.

A major system will always exist, whether or not one is planned. Failure to properly plan a major system will often result in unnecessary flooding and damage. Therefore, it is important to examine grading plans to ensure there is an overland route that has reasonable capacity.

In Calgary, the major system must be designed for the 100 year return period storm. Refer to **Sections 3.1.3** and **6.0 Stormwater Ponds** for more information.

1.3 Level of Service

The purpose of a stormwater drainage system is to provide a high degree of service without causing unacceptable downstream impacts. This is accomplished by balancing the cost of the system with the level of service. In Calgary, the minor storm system must be designed as a separate system from the sanitary; combined systems are not permitted.

Using the Unit Area Release Rate Method (L/s/ha), the minor system must be designed for a recommended minimum release rate of 70 L/s/ha. In steeper terrain, where on-street storage is minimal, the release rate should be higher. The major system must be designed for the 100 year return period storm. A 100 year storm event is assumed to generate runoff conditions that have a probability of 1% to occur in any given year.

Refer to **Section 3.0 Stormwater Design** for more detailed information.

1.4 Planning Levels

1.4.1 Introduction

The integration of municipal land use planning and environmental planning has evolved considerably in the last decade. Aside from water quantity issues, water quality issues must now be given consideration. The preparation of planning documents can provide rationale and direction for the servicing and objectives for future development areas. The intent of this section is to describe the planning levels and provide a general overview. River basin and watershed plans provide a broad scope for drainage planning, while master drainage plans, staged master drainage plans, and biophysical impact assessments provide intermediate planning levels. Detailed information is provided in the subdivision and drainage & site servicing plans, and special projects and contracts. The relationship of these planning levels is illustrated in Figure 1.3. **All plans, reports, and projects must be designed and prepared by qualified consultants.** For more information and specific requirements, see **Section 11.0 Technical Requirements**.

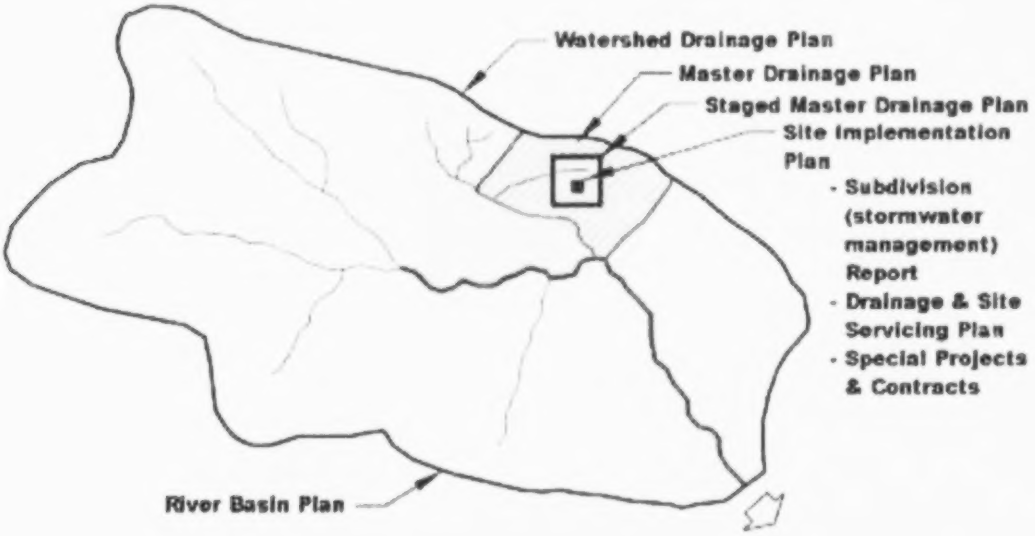
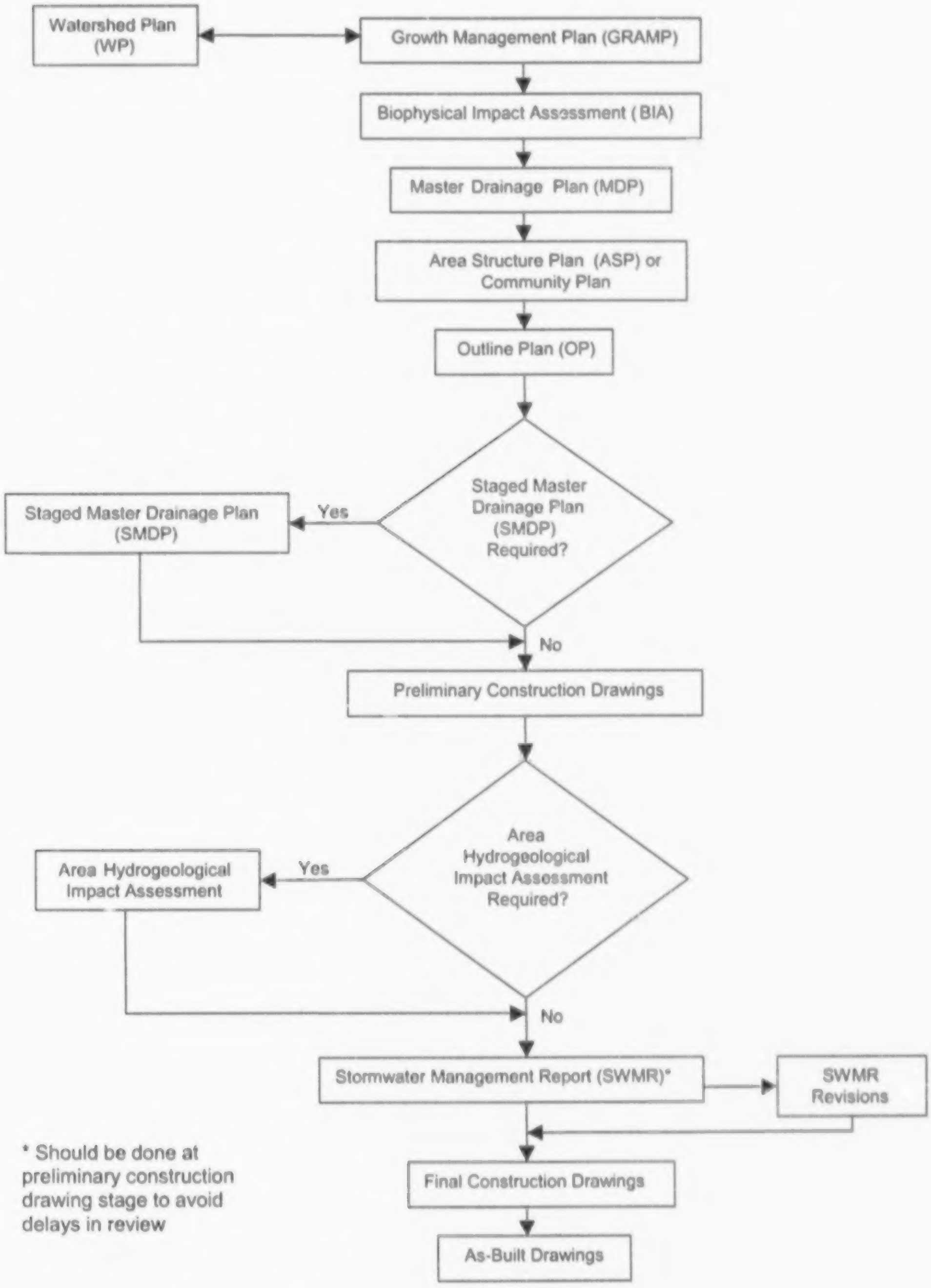

Watershed Drainage Plan
Master Drainage Plan
Staged Master Drainage Plan
Site Implementation Plan
- Subdivision (stormwater management) Report
- Drainage & Site Servicing Plan
- Special Projects & Contracts
River Basin Plan

Figure 1.3: Stormwater Management Planning

In general, system design and analysis should be used to provide a formalized framework for the planning process. The analysis will often include: problem definition, needs analysis, definition of system components, system alternatives, and cost and benefit analysis. The procedure should be used from basic land planning through to detailed design. Repeated application of the process should result in optimal storm servicing. Updating of the key planning and servicing documents is necessary.

Reports are required to establish technical backup demonstrating the viability of proposals, and will ultimately provide the basis for detailed design. Specific sewer and drainage concerns must be addressed at an appropriate and increasing level of detail as the planning and development proceed. Table 1.1 illustrates the planning process.

Table 1.1: Planning Process Flow Chart


Watershed Plan (WP)
Growth Management Plan (GRAMP)
Biophysical Impact Assessment (BIA)
Master Drainage Plan (MDP)
Area Structure Plan (ASP) or Community Plan
Outline Plan (OP)
Staged Master Drainage Plan (SMDP) Required?
Yes
Staged Master Drainage Plan (SMDP)
No
Preliminary Construction Drawings
Area Hydrogeological Impact Assessment Required?
Yes
Area Hydrogeological Impact Assessment
No
Stormwater Management Report (SWMR)*
SWMR Revisions
Final Construction Drawings
As-Built Drawings

* Should be done at preliminary construction drawing stage to avoid delays in review

1.4.2 River Basin Plan (RBP)

River basin planning typically considers the major river basins in Alberta. Calgary is part of the Bow River Basin. Planning issues concern the supply and demand for water as a resource. At this level of planning, the most significant factor is the impact on water quality due to urbanization. As a result, water quality restrictions are starting to be imposed. Stormwater pollution abatement and protection of receiving waters must be recognized.

River basin planning is typically a provincial responsibility. The Province utilizes the Bow River Basin Council as a component of the overall planning structure. Please refer to **Section 11.0 for Technical Requirements**.

1.4.3 Watershed Plan (WP)

Watershed planning typically considers the major tributaries to the major river basins. These storm drainage basins may be either totally or partially within the City boundary. This can include a single drainage basin or a group of sub-basins that contribute to a point in the natural drainage system. Watershed planning can also include both areas proposed for development and those expected to remain undeveloped.

Watershed plans (WP) provide a conceptual framework for stormwater and drainage servicing. Components are usually structural (ie. servicing options, drainage and environmental constraints, best management practices (BMPs) including ponds, alternatives) and non-structural (ie. economic issues, staging, utility corridors, biophysical impact assessments, performance criteria). Although drainage problems are not always evident in the early stages of development, lack of comprehensive planning at this level can lead to long-term flooding and/or pollution problems.

Watershed planning is generally carried out as a joint responsibility between the City of Calgary and the Province. Examples of watershed plan reports include the Fish Creek, Nose Creek and Pine Creek Drainage Studies. Wastewater & Drainage also has available long-range servicing maps; contact the Systems Planning Engineer for more information. Please refer to **Section 11.0 for Technical Requirements**.

1.4.4 Master Drainage Plan (MDP)

A Master Drainage Plan (MDP) is typically a stormwater drainage plan prepared for a large drainage area serviced by a single outfall. Although the MDP is usually for a single outfall, it can include more than one outfall. The drainage area is usually determined based on boundaries imposed by existing drainage boundaries or by watershed plans. The drainage area should not be based on jurisdictional or property boundaries, as this may not provide the best servicing concept for the area. The MDP generally covers a portion of the area served by the watershed plan.

The MDP should be developed through the evaluation of alternatives that provide an acceptable level of service while meeting the objectives of the watershed plan (WP) and satisfying constraints imposed by topography, land uses, and land ownership. The MDP should identify and locate major stormwater ponds, other BMPs, trunk sizes and servicing routes, overland drainage routes, water quality requirements, and land requirements. Preliminary designs of the major ponds and BMPs may be developed and included in the plan.

This level of planning is typically administered by the City of Calgary. Development of the MDP is normally undertaken by Wastewater & Drainage. However, if the area is being developed ahead of the scheduled budget, the developer/consultant will undertake development of the MDP in consultation with the City (Wastewater & Drainage) and the province (Alberta Environment). Please refer to **Section 11.0 for Technical Requirements**.

1.4.5 Staged Master Drainage Plan (SMDP)

A Staged Master Drainage Plan (SMDP) is essentially a stormwater drainage plan prepared for a large area that may or may not be serviced by an outfall. The SMDP generally covers a portion of the area served by the MDP plan. An SMDP is not necessarily required in all circumstances. An MDP may be sufficient provided there is enough detail, the catchment boundaries have not significantly changed, or there is no significant deviation from the stormwater management system proposed. As with an MDP, the drainage area for an SMDP should not be based on jurisdictional or property boundaries, as this may not provide the best servicing concept for the area.

Similar to an MDP, the SMDP should be developed through the evaluation of alternatives that provide an acceptable level of service while meeting the objectives of the watershed plan (WP) or master drainage plan (MDP), and satisfying constraints imposed by topography, land uses, and land ownership. The SMDP should identify and locate major stormwater ponds, other BMPs, trunk sizes and servicing routes, overland drainage routes, water quality requirements, and land requirements. Preliminary designs of the major ponds and BMPs should be developed and included in the plan.

This level of planning is typically administered by the City of Calgary, with the development of the SMDP generally undertaken by the developer/consultant in consultation with the City (Wastewater & Drainage) and the province (Alberta Environment). Please refer to **Section 11.0** for Technical Requirements.

1.4.6 Subdivision Report (SWMR)

Detailed Subdivision Stormwater Management Reports (SWMR) must be prepared for areas covering subdivisions and outline plans. Subdivision reports are commonly referred to as stormwater management reports or overland drainage reports. A subdivision report (SWMR) is required for **each** subdivision development phase, and will correspond to an applicable set of construction drawings. The report will include a detailed hydrologic and hydraulic analysis for the subdivision or outline plan area, and any related details.

At this level, details pertaining to the storm sewer and related structures, hydraulic grade line analysis (where required), 100 year storage requirements, trap lows, escape routes, best management practices (BMPs), and water quality requirements, are some of the items that should be included.

The SWMR is generally undertaken by the developer/consultant. Please refer to **Section 11.0 for Technical Requirements**.

1.4.7 Drainage & Site Servicing Plan (DSSP)

A Drainage & Site Servicing Plan (DSSP) is a drainage and servicing plan that is generally prepared for multi-family, industrial, manufacturing, and commercial areas. The DSSP was formerly known as a Mechanical Site Plan. Larger industrial and commercial areas may also require a Stormwater Management Report (SWMR) to be submitted.

The DSSP must include drainage details such as 100 year volume requirements, trap lows, roof top storage, escape routes, storm and sanitary servicing, and water quality improvements.

The DSSP is generally undertaken by the land owner or their designated consultant. Please refer to **Section 11.0 for Technical Requirements**.

1.4.8 Special Projects and Contracts (SP)

All special projects and contracts (SP) are required to conform to stormwater management designs and policies, whether they are designed within the City by other business units or through external consultants. In general, a Stormwater Management Report (SWMR) must be submitted. If stormwater ponds are required as part of the project, they must be included in the SWMR, submitted as separate reports, or submitted as a Staged Master Drainage Plan (SMDP) report, whichever is appropriate. The type of report required will be dependent on the amount and level of detail required, and the areas serviced. The report(s) should correspond to an applicable set of construction drawings.

The report should include a detailed hydrologic and hydraulic analysis, and provide details pertaining to the storm sewer and related structures, hydraulic grade line analysis, 100 year storage requirements, stormwater ponds, trap lows, escape routes, best management practices (BMPs), erosion & sediment controls, and water quality requirements (as required).

The SP is generally undertaken by the land owner, which is often The City of Calgary. A designated consultant is often used on behalf of the land owner. Please refer to **Section 11.0 for Technical Requirements**.

1.4.9 Biophysical Impact Assessment (BIA)

Environmental planning is an important component to the municipal land use planning process. To ensure overall environmental objectives are being met, a Biophysical Impact Assessment (BIA) is to be conducted.

The Biophysical Impact Assessment is an evaluation of the physical principles and methods that will be applied to biological processes and geographic features. The purpose of the BIA is to examine the potential impacts of development on biophysical elements (ecosystems, landforms and habitats) and to successfully integrate stormwater management (utilities and facilities) within the planning area. This includes an inventory of the following:

- Topography
- Geology and Geomorphology
- Vegetation
- Wildlife
- Hydrology
- Fisheries
- Aesthetics
- Cultural Resources

A BIA is an effective information tool that aids the decision making process. To be effective, the BIA is to be done in collaboration with Park Development & Operations and Wastewater & Drainage to meet mutual objectives. The consultant is to contact Park Development & Operations for BIA scope, requirements and issues to be addressed. A BIA may be quite simple or complex depending on the area (community) and/or size. Environmental strategies may be provided in the Natural Area Management Plan (NAMP) prepared by Park Development & Operations. If a NAMP is available for the area, natural habitat types are identified. For more information, see **Section 11.1.9**.

2.0 Approvals & Processes

2.1 General

This section has been prepared to outline the procedures and approvals required for construction of stormwater drainage systems. It is the responsibility of the land owner or developer undertaking the project (or their designated consultant) to comply with the statutory requirements governing the work. Approvals from the required authorities having jurisdiction are required; this includes but is not limited to those mentioned in the following sections.

The owner or developer (or designated consultant) is responsible for preparing the applications and required information, which must then be forwarded to Wastewater & Drainage. Wastewater & Drainage will make the formal application(s) to the required authorities having jurisdiction; The City of Calgary is typically the permit holder. Contact Wastewater & Drainage for application and information requirements. Construction of work is **not** permitted without the necessary permits or approvals in place.

Where bylaws, acts, regulations, policies, and standards are referred to, this shall mean the most recent edition or amendment.

There are three jurisdictions that may require approval for construction of stormwater systems or works. This includes the federal government, provincial government and municipal government.

2.2 Federal

2.2.1 Navigable Waters Protection Act

Should an improvement involve construction or placement in, on, over, under, through or across any "navigable water", such as the Bow River, either a permit or an exemption from the requirement must be obtained from the Department of Navigable Waters. "Navigable water" includes a canal and any other body of water created or altered as a result of the construction of any work. Typically this work would include storm outfalls, crossings and riverbank stabilization.

Wastewater & Drainage will make the application to Navigable Waters on behalf of the owner or developer (or their designated consultant).

2.2.2 Fisheries Act

The main part of the Fisheries Act dealing with the protection of fish habitat is a straightforward prohibition that states "no person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat". Where work or an improvement causes the alteration, disruption or destruction of fish habitat, legal Authorization (exemption) must be obtained from the Department of Fisheries and Oceans. If an exemption is granted, the "alteration, disruption or destruction" of fish habitat will be subject to conditions prescribed in the Authorization document. Authorizations are used as a last resort when there is no other way to preserve fish habitat. It is the responsibility of the owner or the developer (or their designated consultant), to comply with the conditions set out in the Authorization. A report from a qualified fisheries consultant may be required prior to Authorization being issued.

Wastewater & Drainage will make the application to Fisheries and Oceans on behalf of the owner or developer (or their designated consultant).

2.3 Province of Alberta

2.3.1 Environmental Protection and Enhancement Act

On September 1, 1993, Alberta's Environmental Protection and Enhancement Act (EPEA) and its associated regulations came into force, replacing nine former acts. The purpose of the Act is to support and promote the protection, enhancement and wise use of the environment. In general, the Act specifies what is to be regulated, the regulatory processes and application. Also refer to "Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems" by Alberta Environmental Protection (1997) for further information.

2.3.2 Wastewater and Storm Drainage Regulation (Alberta Regulation 119/93)

i. Storm Drainage System

Pursuant to the EPEA, Wastewater and Storm Drainage Regulation, authorization is required from Alberta Environment for the construction of **storm drainage systems for subdivisions** approved by the City of Calgary.

The City of Calgary (Urban Development) will apply for authorization and submit engineering drawings provided by the owner or developer (or their designated consultant) to Alberta Environment as required. See also Figure 2.1.

ii. Stormwater Ponds and Outfalls

Pursuant to the EPEA, approval is required for the construction of **stormwater ponds and outfalls**. The owner or developer (or designated consultant) is responsible for preparing and submitting the information to Wastewater & Drainage. Wastewater & Drainage will apply for approval to Alberta Environment. A 30 day public notification period is required. Refer to

Appendix A for required information.

Wastewater & Drainage will make the application to Alberta Environment on behalf of the owner or developer (or their designated consultant).

Construction drawings for subdivision ponds and outfalls are submitted to Alberta Environment by Urban Development. Wastewater & Drainage will submit construction drawings for retrofit ponds and outfalls directly to Alberta Environment.

2.3.3 Water Act

Pursuant to the Water Act, approval is required for construction of stormwater outfalls or any work involving instream or bank disturbances. A license is required to impound water for the purpose of water management, flood control, flow regulation, or the diversion of water. Applications should be made to Alberta Environment, Water Administration. Wastewater & Drainage will apply for authorization on behalf of the owner or developer (or designated consultant).

2.3.3.1 Dam and Canal Safety

Dam and Canal Safety is covered under part 6 of the Water Act, Water (Ministerial) Regulation (Alberta Regulation 205/98). A "dam" is defined as a "barrier constructed for the purpose of storing water, including water containing any other substance, that

i. provides for a storage capacity of 30 000 cubic metres or more, **and**
ii. is 2.5 metres or more in height when measured vertically to the top of the barrier,
    (a) from the bed of the water body at the downstream toe of the barrier, where the barrier is across a water body, or
    (b) from the lowest elevation at the outside limit of the barrier, where the barrier is not across a water body.

If a stormwater pond meets the above criteria, additional review and approval under part 6 of the Water Act, Water (Ministerial) Regulation would also be required. The owner or developer (or designated consultant) may apply directly to Alberta Environment, Municipal Approvals. The project will be referred to the Dam Safety and Water Projects Branch as part of the review process. A geotechnical report should accompany the application.

2.3.4 Calgary Restricted Development Area Regulation

Under the Government Organization Act, any surface disturbing activity or change in land use within areas governed by the Restricted Development Area Regulation requires the consent of the Minister of the Environment. In Calgary, this includes lands in the Transportation Utility Corridor (TUC). The owner or developer (or designated consultant) should contact the TUC Coordinator at Alberta Environment directly regarding TUC issues.

2.3.5 Public Lands Act

Where a proposed facility may encroach on crown lands, disposition and/or a License of Occupation is required under the Public Lands Act. This also applies to facilities or work that affects all permanent and naturally occurring bodies of water, and all naturally occurring rivers, streams, watercourses and lakes. Construction of outfalls discharging to a major watercourse would be an example.

Where a License of Occupation is involved, Wastewater & Drainage will apply directly to Alberta Environment on behalf of the owner or developer (or designated consultant). In this situation, two approvals are required, one under the Public Lands Act and another under the Water Act. A one-window application process can be used for both applications. Where disposition is involved, the owner or developer (or designated consultant) should apply directly to Public Lands Alberta, Department of Agriculture, Food and Rural Development.

2.3.6 Stormwater Reports

All Master Drainage Plan reports, Staged Master Drainage Plan reports, and Stormwater Pond reports must be reviewed by Alberta Environment. Wastewater & Drainage will forward copies of the report(s) to Alberta Environment for review.

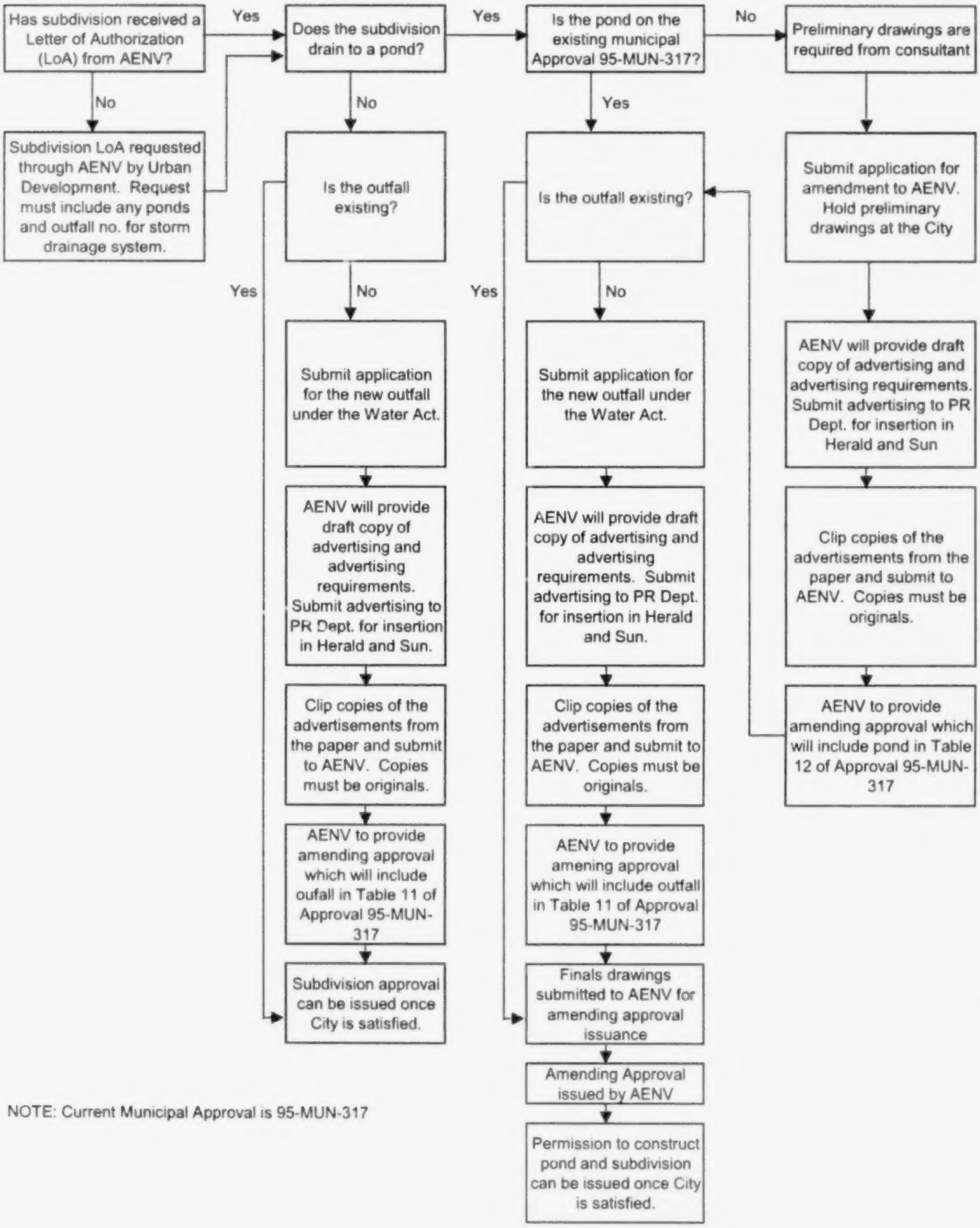
2.4 City of Calgary

There are two departments in The City of Calgary that must review and approve stormwater drainage systems: Wastewater & Drainage and Park Development & Operations.

2.4.1 Wastewater & Drainage

Wastewater & Drainage is responsible for reviewing stormwater reports and construction drawings. All reviews and/or approvals from the various jurisdictions must be in place prior to issuance of construction permission by the City. Figure 2.1 and **Appendix A** illustrate the subdivision, outfall, and pond approval process with Alberta Environment.

Figure 2.1: Subdivision and Pond Approvals Process-Coordination with Alberta Environment


Has subdivision received a Letter of Authorization (LoA) from AENV?
Yes
No
Subdivision LoA requested through AENV by Urban Development. Request must include any ponds and outfall no. for storm drainage system.
Does the subdivision drain to a pond?
Yes
No
Is the outfall existing?
Yes
No
Submit application for the new outfall under the Water Act.
AENV will provide draft copy of advertising and advertising requirements. Submit advertising to PR Dept. for insertion in Herald and Sun.
Clip copies of the advertisements from the paper and submit to AENV. Copies must be originals.
AENV to provide amending approval which will include oufall in Table 11 of Approval 95-MUN-317
Subdivision approval can be issued once City is satisfied.
Is the pond on the existing municipal Approval 95-MUN-317?
No
Yes
Is the outfall existing?
Yes
No
Submit application for the new outfall under the Water Act.
AENV will provide draft copy of advertising and advertising requirements. Submit advertising to PR Dept. for insertion in Herald and Sun.
Clip copies of the advertisements from the paper and submit to AENV. Copies must be originals.
AENV to provide amening approval which will include outfall in Table 11 of Approval 95-MUN-317
Finals drawings submitted to AENV for amending approval issuance
Amending Approval issued by AENV
Permission to construct pond and subdivision can be issued once City is satisfied.
Preliminary drawings are required from consultant
Submit application for amendment to AENV. Hold preliminary drawings at the City
AENV will provide draft copy of advertising and advertising requirements. Submit advertising to PR Dept. for insertion in Herald and Sun
Clip copies of the advertisements from the paper and submit to AENV. Copies must be originals.
AENV to provide amending approval which will include pond in Table 12 of Approval 95-MUN-317

NOTE: Current Municipal Approval is 95-MUN-317

i. All stormwater reports (Master Drainage Plan, Staged Master Drainage Plan, Subdivision, Stormwater Ponds, and Biophysical Impact Assessment and Drainage & Site Servicing Plans (as required)) must be submitted for review and approval by Wastewater & Drainage. Refer to **Section 11.0 Technical Requirements**.

ii. All Master Drainage Plan reports, Staged Master Drainage Plan reports, and Stormwater Pond reports must be additionally reviewed by Alberta Environment. Wastewater & Drainage will forward copies of the report(s) to Alberta Environment for review.

iii. All Biophysical Impact Assessments (BIAs) must be reviewed and supported by Park Development & Operations. Park Development & Operations must support Watershed Plans and/or Master Drainage Plan Reports that are impacted by the BIAs. Where required, Park Development & Operations will inform the River Valleys Committee of report submissions; see **Section 2.4.3** regarding the mandate of the River Valleys Committee.

Although it is not mandatory, the owner or developer (or designated consultant) is encouraged to meet and discuss the planned proposal with the River Valleys Committee, Park Development & Operations, and Wastewater & Drainage prior to preparing the final report(s), for areas within river valleys. Communication in the early planning stages among all of the groups will provide an opportunity for a unified solution that will advance the subsequent approval and construction processes. The owner or developer (or designated consultant) may forward copies of the report(s) or pertinent information to these groups as required. In addition, Alberta Environment, Water Sciences Branch, must review BIAs where ponds are adjacent to watercourses.

iv. All preliminary and final subdivision construction drawings (including landscaping drawings) must be submitted for review and approval. Construction drawings must be submitted directly to Urban Development; Urban Development will then circulate the drawings to Wastewater & Drainage and other business units as required.

Urban Development will also circulate construction drawings for stormwater ponds and outfalls to Alberta Environment as part of the application and approval process required by Alberta Environment. Wastewater & Drainage will submit construction drawings for retrofit ponds and outfalls directly to Alberta Environment.

v. Special drainage projects, stormwater ponds and outfalls require the review and approval of Wastewater & Drainage.

2.4.2 Park Development & Operations

Park Development & Operations is involved in the review and approval of Biophysical Impact Assessments and support of Watershed Plans and/or Master Drainage Plan Reports as they pertain to stormwater pond locations, sizes and impacts to the adjacent areas and the Master Urban Park Plan. This also includes outfalls and other special drainage features.

Park Development & Operations must be included in the planning and development of Biophysical Impact Assessments and Watershed Plans and/or Master Drainage Plan Reports as early as possible in the process. It is the responsibility of the owner or developer undertaking the work (or their designated consultant) to work jointly with Park Development & Operations and Wastewater & Drainage towards an acceptable unified solution.

Wastewater & Drainage will not issue approval for Watershed Plans and/or Master Drainage Plan Reports until Park Development & Operations supports the recommendations in the BIA report(s). The BIA is to be done in collaboration with Park Development & Operations and Wastewater & Drainage to meet mutual objectives.

2.4.3 River Valleys Committee

The River Valleys Committee (RVC) was established in 1990. The River Valleys Committee is an independent volunteer group that is mandated to provide advice to City Council regarding development and maintenance of Calgary's river valley systems. In general, this includes recreational and environmental activities or projects that affect floodplain management, water quality and direct impact to the rivers.

RVC provides a structure and forum for a partnership with communities, individuals and other volunteer groups. Although the Committee is a component of the Calgary Parks Foundation, a unique joint-venture partnership exists with the two groups. The River Valleys Committee reports to City Council through the Parks Foundation's Board of Governors when circumstances are warranted.

The River Valleys Committee is typically interested in stormwater ponds and outfalls, and in particular, how they impact water quality to receiving streams. It is the responsibility of the Planning Policy and Park Development & Operations departments to circulate planning applications to the River Valleys Committee. Although it is not mandatory, the owner or developer (or designated consultant) is encouraged to meet and discuss potentially contentious issues with the River Valleys Committee in advance. Communication in the early planning stages among RVC, Park Development & Operations, and Wastewater & Drainage will provide an opportunity for a unified solution that will advance the subsequent approval and construction processes.

Although RVC is a non-regulatory agency, they may be included in the development and/or review process for Biophysical Impact Assessments and Watershed Plans and/or Master Drainage Plan Reports as required. This mainly applies to areas within river valleys.

2.4.4 Bow River Basin Council

The Bow River Basin Council (BRBC) is a non-profit organization whose mandate is to conduct activities for the improvement and protection of the water of the Bow River Basin (Alberta) watershed. In Calgary, the Bow River Basin encompasses the Bow River, Elbow River, Nose Creek, West Nose Creek and Fish Creek. The BRBC recognizes the Bow River Basin as a fragile and unique resource that should be conserved and protected by balancing multiple uses and ensuring that the needs of all stakeholders are met.

The objectives of the Bow River Basin Council are achieved by:

- sharing perspectives and exchanging information,
- prioritizing water use management issues that may affect the quality or quantity of groundwater or surface water, riparian zones or aquatic ecosystems,
- participating in water use and planning activities,
- developing water use management procedures and performance measures,
- encouraging the implementation of cooperative water use management strategies, and
- participating in activities that promote increased awareness of water use management activities.

The Bow River Basin Council is typically interested in river basin planning issues. Although the BRBC is a non-regulatory group, it is important to involve them in River Basin studies, and where required, in Watershed studies. One of the current goals of BRBC is to determine and help set future in-stream water quality objectives. The Elbow River reach just upstream of Glenmore Reservoir is currently undergoing this process. In time, these in-stream objectives may form part of the provincial regulatory requirements for water quality.

3.0 Stormwater Design

3.1 Drainage System

3.1.1 Policy, Goals and Objectives

Urban development can alter the hydrology of the landscape and adversely affect water quality. With development, land uses change and the amount of stormwater runoff generally increases. There are a number of ways to manage stormwater from a site. This includes conveyance, storage, treatment and infiltration. The overall goal of stormwater management is to improve water quality and address water quantity problems through the implementation of stormwater controls and practices. This closely relates to the goal of The City of Calgary to *"provide excellent and affordable storm sewer systems to protect Calgarians, their property and the environment"*,

Good planning and design is critical to successful stormwater management. To help achieve these stormwater management goals, all new development areas in Calgary must be designed using the Dual Drainage Concept (minor/major system) to achieve specific service level objectives and utilize Best Management Practices for water quality enhancement (See **Section 8.0**).

3.1.2 Minor System

Traditional stormwater drainage systems have typically consisted of an underground network of pipes and associated structures. This system was designed to transport flows for relatively minor, or low intensity rainstorms, as a matter of convenience. The **minor** system provides a basic level of service by conveying flows from the more common (low intensity, more frequent) rainstorm events.

The minor stormwater drainage system consists of the underground pipe network and its associated structures. These components facilitate the transport of stormwater flows from minor rainstorms. Components of the minor system typically include:

- Gutters and roof leaders
- Weeping tile
- Lot drainage
- Catchbasins, inlets and leads
- Underground pipe system
- Manholes and junctions
- Outfalls
- Receiving waters

Some components, such as gutters and roof leaders, may be classified under both minor and major system components, since they are considered in the design of each type of system.

3.1.2.1 General Requirements

i. The storm sewer pipe (minor) system must be designed as a **separate system** from the sanitary. Combined systems are not permitted.

ii. In general, the storm sewer must be designed to convey design flows when flowing full with the hydraulic grade line (HGL) at or below the crown of the pipe. Sewer pipes should not surcharge for design or 100 year flows unless previously approved by Wastewater & Drainage. **Surcharge to ground surface is strictly prohibited.**

iii. The minor system is to be designed according to the level of service stipulated in **Section 3.1.2.2**.

3.1.2.2 Level of Service

A basic level of service is provided by the minor system. In Calgary, this has typically been sized for the 5 year return period storm since 1952. Prior to 1952, the level of service was based on a 2 year return period storm. In Calgary, sizing of the storm trunks was previously done using the **Rational Method** design. Unfortunately, when the drainage area exceeds 30 ha, there is a marked inequity in trunk capacity (expressed as capacity per hectare drained) in the downstream direction.

To avoid these inequities, the City of Calgary has adopted a new approach to storm trunk design. This is known as the **Unit Area Release Rate Method**. This method uniformly distributes the storm trunk capacity, on a per hectare basis, for the area tributary to the storm trunk. Refer to "Stormwater Management Methodology" by Reid Crowther & Partners Ltd. (1992) for more information.

For all new areas, the minor system must be designed using the Unit Area Release Rate Method (L/s/ha). In general, the recommended minimum release rate is 70 L/s/ha. In steeper terrain, where on-street storage is minimal, the design rate must be higher. Refer to the following sections for more information.

3.1.2.3 Unit Area Release Rate Method

For all new areas, the minor system must be designed using the Unit Area Release Rate Method (L/s/ha). The recommended minimum release rate required is 70 L/s/ha.

The Unit Area Release Rate method formula is expressed as:

$$Q = URR \times A \qquad \textbf{Equation 3.1}$$

where:
Q = peak runoff rate (L/s)
URR = unit area release rate (L/s/ha)
A = area of the drainage basin (ha)

Recommended unit area release rates are as follows:

i. **70 L/s/ha**-The **recommended minimum** release rate shall be 70 L/s/ha. This rate is to be used in relatively flat areas where trap low storage is not limited.

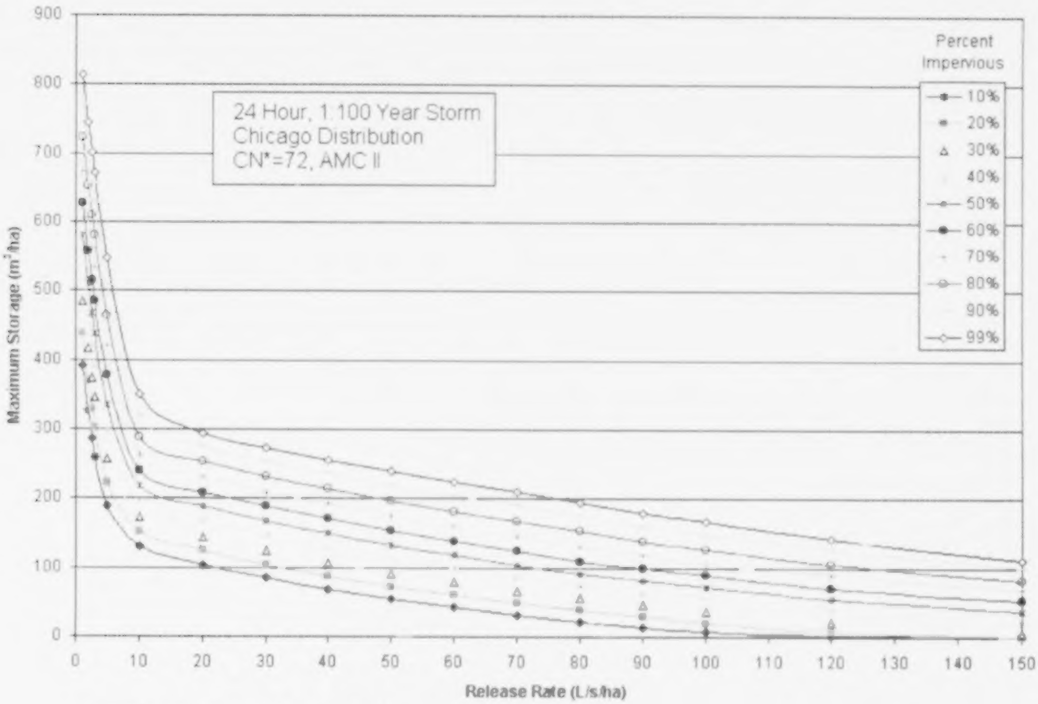
ii. **80-90 L/s/ha**- Higher release rates should be used in areas of moderate slopes where trap low storage is limited. The required release rate(s) should be established by the consultant.

iii. **100-120 L/s/ha**- High release rates should be used in steep areas where trap low storage is greatly limited or for areas with high densities. The required release rate(s) should be established by the consultant.

iv. Unit area release rates smaller than 70 L/s/ha will be considered on a site-specific basis only; approval from Wastewater & Drainage is required. In no circumstances will a rate lower than **50 L/s/ha** be permitted. The consultant must be able to demonstrate that sufficient trap low storage is available. In general, this release rate will only be considered in flat areas or for areas adjacent to stormwater ponds where overland flows can be better utilized.

v. All unit area release rates should be established at the time of the Master Drainage Plan report where possible to allow sizing of the storm sewer trunk, but no later than the Staged Master Drainage Plan report. Figure 3.1 provides a preliminary planning tool for selection of unit area release rates for an area. However, this figure is a planning tool only and does not replace detailed modelling to determine the most appropriate release rates.

Maximum Storage vs Percent Impervious and Release Rate



Source: Bert van Duin (403)264-9366

Figure 3.1: Unit Area Release Rate vs. On-Site Storage

3.1.2.4 Modified Unit Area Release Rate Method

Until such time as all drainage catchments are designed using the Unit Area Release Rate Method, a modified method may have to be used for design of the minor system. The modified method should only be used when there is sufficient drainage area remaining in a catchment (> 30 ha), there are no stormwater ponds, and where the storm trunk was originally designed using the Rational Method. The modified method involves distributing the remaining storm trunk design capacity at a designated location uniformly among the remaining drainage area. This will result in a modified unit area release rate that will be used to size the lateral storm sewer. However, as long as the remaining drainage area can drain to a stormwater pond, the Unit Area Release Method as described in **Section 3.1.2.3** must be used.

The Modified Unit Area Release Rate method formula is expressed as:

$$Q = MURR \times A \qquad \text{Equation 3.2}$$

where:
Q = peak runoff rate (L/s)
$MURR$ = modified unit area release rate (L/s/ha)
A = area of the drainage basin (ha)

3.1.2.5 Rational Method

The Rational Method can be used for the design of the minor system for **remaining catchment areas** that were originally designed using this method, provided the remaining area is ≤ 30 ha. Areas larger than 30 ha should be designed using the Unit Area Release Rate Method or the Modified Unit Area Release Rate Method. The use of the Rational Method should be limited where possible.

The Rational Method is a runoff estimation method based on an empirical formula relating the peak flow rate to the drainage area, rainfall intensity, and a runoff coefficient. The method has been widely used due to its simplicity, but to this day its limitations are still not fully understood. As a result, The City of Calgary is moving away from this method.

The rational formula is expressed as:

$$Q = 2.78\ CiA \qquad \text{Equation 3.3}$$

where:
Q = peak runoff rate (L/s)
2.78 = constant
C = runoff coefficient
i = intensity of the rainfall (mm/hr) for a storm duration equal to t_c
A = area of the drainage basin (ha)
t_c = time of concentration for the basin (min.)

The intensity (i) is obtained from an Intensity-Duration-Frequency curve (IDF) derived from rainfall records for Calgary. The 5 year intensity curve is derived by the following formula (see also Figure 3.2):

$$i = 1651/(t_c + 10) \quad \text{(mm/hr)} \quad \text{Equation 3.4}$$

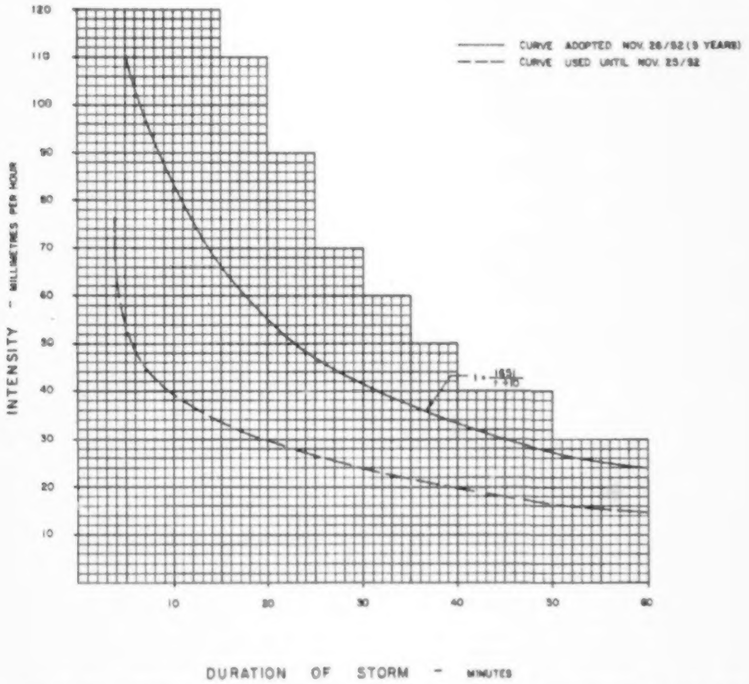


Figure 3.2: Storm Sewer Design Curve for Rational Method

A sewer design table or calculation sheet can be used to size the sewer pipe:

Table 3.1: Storm Sewer Design Table

AREA NO ____________ DESIGNED BY ____________ DATE __________ PAGE __________ OF __________

LOCATION LINE	FROM	TO	INCREMENT AREA NUMBER	INCREMENT AREA HECTARES (ha)	RUNOFF FACTOR "C"	EQUIVALENT AREA C×100% HECTARES	TOTAL AREA C×100% HECTARES	TIME OF CONCENTRATION MINUTES (min)	INTENSITY I (mm/h)	Q=2.78 CIA (m³/s × 10⁻³)	SLOPE	DIAMETER OF PIPE (mm)	VELOCITY FLOWING FULL (m/s)	LENGTH OF LINE METRES (m)	TIME OF FLOW MINUTES (min)	CAPACITY OF PIPE (m³/s × 10⁻³)

See **Section 3.2.5.1** for more information regarding runoff coefficients.

3.1.3 Major System

The major stormwater drainage system conveys runoff from extreme rainfall events that are in excess of the minor underground system. Components of the major system typically include:

- Gutters and roof leaders
- Lot drainage
- Roads
- Swales
- Trap lows
- Escape routes
- Storage facilities (stormwater ponds)
- Culverts
- Outfalls
- Receiving waters

Some components, such as gutters and roof leaders, may be classified under both minor and major system components, since they are considered in the design of each type of system.

A major system will always exist, whether or not one is planned. Failure to properly plan a major system will often result in unnecessary flooding and damage. Therefore, it is important to examine grading plans to ensure there is an overland route that has reasonable capacity.

3.1.3.1 General Requirements

i. The major system must be designed as an overland system.

ii. A continuous escape route must be provided for the overland flows. Adjacent properties must be protected from flooding by these flows.

iii. The major system is to be sized according to the level of service stipulated in **Section 3.1.3.2**.

3.1.3.2 Level of Service

In Calgary, the major system must be designed for the 100 year return period storm. This includes all stormwater ponds. This is to provide a reasonable level of flood protection. Refer to **Section 3.2.4 Design Storm** and **6.0 Stormwater Ponds** for more information.

3.2 Runoff Analysis

3.2.1 General

The stormwater runoff process involves the interaction of a number of phenomena. This includes assessment of the precipitation event, interception and depression storage, evaporation, and infiltration. Although there are different methods to estimate runoff flows and volumes, care should be taken with the application of the analysis, considering the complexity of the runoff process. The analysis requires an understanding of the runoff process and the methodology used to model the process.

Several estimation methods are available to determine runoff. This includes:

- Rational Method
- Isochrone Method
- SCS Method
- Horton Method
- Deterministic Methods

These methods are described further in "Stormwater Management Guidelines for the Province of Alberta" (1999).

3.2.2 Computer Models

Numerous computer models have been developed that can model both hydrological and/or hydraulic analyses. Unfortunately, there are relatively few models that are designed as general application models that can be applied to a wide variety of design situations. The models that can do this tend to require extensive input data and a considerable level of expertise to ensure proper program usage. It is important to recognize that computer models are a design tool and should not be solely relied on for their analytical results. As computer models are redeveloped, some of the older models such as OTTHYMO/INTERHYMO, OTTSWMM and QUALHYMO may no longer be available for purchase.

3.2.2.1 General

i. Computer modelling is required for derivation of the 100 year flow rates and volumes, unless specified otherwise.

ii. When choosing a computer model, it is important to consider the data and model limitations. The selection and proper application of the computer model is primarily the responsibility of the developers and their consultants. The models must be approved by Wastewater & Drainage.

iii. In general, DDSWMM, OTTHYMO, and SWMHYMO are recommended for use in the design of dual (minor and major) drainage systems. EXTRAN is recommended for surcharge analysis and special hydraulic situations.

iv. QUALHYMO, QHM, and SWMM (and XP-SWMM) are the models recommended for use in stormwater pond design for water quality and storage volume. Storage volumes also require the use of OTTHYMO, or associated model derivatives for comparison purposes. See **Sections 3.2.3, 7.5, and 7.6** for more information.

3.2.2.2 OTTHYMO/INTERHYMO

OTTHYMO is a hydrologic model used for stormwater management and flood control. The model was originally derived from the HYMO computer model and uses all of the HYMO commands (see "Stormwater Management Guidelines for the Province of Alberta" for more information). The additional commands URBHYD, NASHYD and KINROUTE, which was developed by the IMPSWM group, were also incorporated into the model, as was the modified SCS curve number, CN*.

The URBHYD subroutine is designed to produce results similar to the RUNOFF block in the model SWMM for large catchment areas. URBHYD differs from the RUNOFF block in that it uses unit hydrographs derived from a synthetic linear reservoir system to simulate the effect of overland flows. Runoff hydrographs for pervious and impervious surfaces are generated.

The NASHYD subroutine allows for the use of the NASH unit hydrograph or the Williams and Hann unit hydrograph used in HYMO. KINROUTE is a subroutine used to route flows through pipe systems based on the diffusive kinematic wave model. However, backwater effects cannot be simulated.

INTERHYMO is a more recent version of OTTHYMO that was developed by Paul Wisner & Associates in 1989. INTERHYMO incorporates new subroutines that include the derivation of design storms, quasi-continuous simulations, lagging and shifting of hydrographs, and interface with EXTRAN.

3.2.2.3 SWMHYMO

SWMHYMO is a redevelopment of the OTTHYMO model. SWMHYMO is a complex hydrologic model that is used for the simulation and management of stormwater runoff in large and small urban and rural areas. In 1994, SWMHYMO was created by Mr. J.F. Sabourin to respond to increasing stormwater management needs and improved computer systems.

One of the main improvements of the program is the ability to multi-task through the Windows environment. Online help is available along with pull-down menus for creating data input files, default value files, output files, and storm and hydrograph files. Also included is an integrated printing utility for printing enhancements.

Unlike OTTHYMO, SWMHYMO is able to undertake limited continuous rainfall simulations, as well as single rainfall event simulations through the incorporation of new commands. Improvements were also made to the ROUTE RESERVOIR command to allow overflow diversions. The new COMPUTE DUALHYD command allows flow to be split into major and minor systems, and the effects of surface storage at street trap lows to be determined.

3.2.2.4 SWMM

SWMM, Stormwater Management Model, was developed by the United States Environmental Protection Agency (USEPA) in 1969-1971. It has been continually maintained and updated, and is perhaps the best known and widely used of the available urban runoff quantity and quality models in North America; it is also one of the most comprehensive modelling programs available for urban drainage analysis. SWMM is a dynamic model that is capable of simulating nonpoint source runoff quality and routing, as well as storage, treatment and other BMPs. The model can simulate a wide range of pollutants and is capable of both continuous and single event simulations. Version 4.3 and later versions are more complex in the characterization of washoff processes and stormwater runoff systems.

SWMM is composed of several blocks that can be linked together or operated as separate programs. There are six blocks: Runoff, Transport, Extran, Storage/Treatment, Receive, and Combine.

The RUNOFF block generates hydrographs and routes overland runoff using the kinematic wave method through non-linear reservoir routing. The RUNOFF block also generates pollutographs.

The TRANSPORT block simulates free surface flow through drainage conveyance systems (pipes or channels) by means of a modified kinematic wave formulation. Although the conveyance system is simulated, surcharge or pressurized flow cannot be simulated with this block.

EXTRAN is a sophisticated pipe routing program that can model complex sewer systems. EXTRAN simulates backwater conditions, looped pipe system, flow reversals, and surcharged flow conditions by the use of the complete St. Venant (dynamic flow) equations. The program has been used quite extensively for hydraulic analysis.

The STORAGE/TREATMENT block simulates the impact of storage on stormwater effluent quality, while the RECEIVE block simulates the impact of stormwater effluent quality on the receiving stream.

The COMBINE block is a utility routine that facilitates the modelling of systems that are too large to model as a single system. COMBINE can also be used to collate data sets and/or combine data sets from one model run for input into another model.

3.2.2.5 OTTSWMM

There are a number of models that are modified versions of SWMM. OTTSWMM is one such model. OTTSWMM (University of Ottawa Storm Water Management Model) is a discrete model that was developed for the analysis of dual drainage systems; it was first released in 1985. Runoff is computed and routed through both the minor system and major system. An important feature of the model is its ability to model the hydraulic capacity of storm inlets. OTTSWMM is composed of four sub-models: surface runoff, inlet, minor system, and major system. Sub-models have also been included for the design/analysis of storage facilities in the minor and major systems. EXTRAN can be interfaced with the model for surcharge analysis.

3.2.2.6 DDSWMM

DDSWMM (Dual Drainage Storm Water Management Model) is a new and improved release of the OTTSWMM model. DDSWMM was first released in 1996. As with OTTSWMM, DDSWMM is capable of analyzing dual drainage systems by utilizing the same four sub-models (surface runoff, inlet, minor system, and major system) and the storage sub-models. DDSWMM was designed to interface with the new improvements to EXTRAN.

The flow routing methodology in DDSWMM has also been improved. Although the basic routing algorithm is the same as OTTSWMM, a more elaborate procedure is used in analyzing the network. A kinematic wave model is used in the routing procedure.

3.2.2.7 XP-SWMM

XP-SWMM is a state-of-the-art hydrologic and hydraulic model. The model is an enhanced version of SWMM with an XP interface. The graphical EXPERT environment (XP) provides a user-friendly, graphics-based environment for data entry, run-time graphics, and results in graphical form. Drainage systems can be drawn on the screen or imported from a database.

As with SWMM, three methods of hydraulic analysis are available: non-linear reservoir routing (RUNOFF), non-linear kinematic wave (TRANSPORT), and full dynamic wave (EXTRAN).

3.2.2.8 QUALHYMO

QUALHYMO is a planning level model that simulates water quality and quantity. The model was developed in 1983 at the University of Ottawa with a grant funded by the Ontario Ministry of Environment. The model was originally designed to be a simple seasonal continuous water quality/quantity simulation model for lumped applications in urbanizing Ontario river basins. The intent was to supplement existing models with a flexible and economical model that had a reasonable scope of simulation. The model is capable of both continuous and single event simulations.

The basic structure of QUALHYMO is based on the HYMO and OTTHYMO models. A number of alternate commands were incorporated to expand the scope of the model. Some of these commands include GENERATE, POND, POLLUTANT RATES, CALIBRATE and EXCEEDANCE CURVES. These commands make QUALHYMO distinct in its ability to simulate the generation and routing of pollutants, snowmelt, simplified soil freeze-thaw and instream erosion potential. QUALHYMO is one of the simpler and less costly simulation models available.

3.2.2.9 QHM

QHM is a Windows-based watershed quantity and quality simulation model that is intended for watershed management and stormwater design. QHM was derived from the QUALHYMO model and therefore has similar features to QUALHYMO. QHM is capable of simulating rainfall-runoff, soil and groundwater effects on baseflow, evapo-transpiration, soil freeze-thaw, snowmelt and snow removal/disposal, soil erosion and urban runoff quality (pollutants). Although QHM is primarily used for continuous simulation, single event simulation is also possible.

3.2.2.10 EXTRAN

Although EXTRAN is one of the blocks in the SWMM model, it can be used as a separate program. EXTRAN is a sophisticated pipe routing program that can model complex sewer systems. EXTRAN simulates backwater conditions, looped pipe systems, flow reversals, and surcharged flow conditions by the use of the complete St. Venant (dynamic flow) equations. Although EXTRAN originally contained both quality and quantity sub-routines, the quality sub-routine was eventually removed due to the wide-spread use for hydraulic analysis.

3.2.2.11 Other Models

Other computer models are available such as STORM and receiving stream water quality models (HSPF, QUAL2E-U and WASP5). Refer to Alberta Environmental Protection's "Stormwater Management Guidelines for the Province of Alberta" (1999) for more information. However, computer modelling technology is evolving and new models may become available. Contact Wastewater & Drainage for approval of computer models not listed.

3.2.2.12 Calibration

Model calibration and verification is important to ensure the accuracy of the model outputs. Unfortunately there is a lack of measured data and verification becomes more difficult. Wastewater & Drainage is currently undertaking a two year monitoring study within the city to determine model calibration and stormwater total loadings. The program will include a water quality and quantity program, and detailed computer modelling and analyses. Stormwater quantity and quality methodologies and parameter sensitivities will be addressed. In the interim, care should be taken in the selection of modelling parameter values. Some recommendations are made in the following sections.

3.2.3 Single Event vs. Continuous

Stormwater computer models can be used to model a drainage system for either single or continuous rainfall events. A single event model is defined as a simulation of a short defined storm event with subjective start-up conditions, while a continuous model is a simulation that models both dry and wet hydrology processes using a continuous record of atmospheric data.

In single event modelling, a single storm event ranging in duration from 1 hour to 24 hours is modelled to determine stormwater runoff for a drainage area. The storm event modelled is normally the 100 year design storm. Single event models typically used include DDSWMM, OTTHYMO and SWMHYMO.

For continuous modelling, runoff for a drainage area is modelled for a prescribed period of time, typically several years. A precipitation file, normally generated by Meteorological Service of Canada, is incorporated into the continuous model. The precipitation file typically includes hourly rainfall amounts that have been collected over the years. Temperature files can also be used to model snowmelt. SWMM (and XP-SWMM), QUALHYMO and QHM are the most frequently used continuous models. With continuous models, water quality and quantity can both be modelled. Continuous models also have the advantage of being able to simulate and account for dry weather processes such as pollutant build-up, evapo-transpiration, storage depletion, moisture conditions, and any processes associated with the winter seasons.

i. Single event simulation must be used to model dual drainage systems.

ii. Continuous simulation must be used to model water quality (sediment removal) and quantity for all stormwater ponds. Refer to **Section 7.0 Water Quality** for further information.

iii. Single event simulation must also be used to model water quantity for all stormwater ponds. A comparison must be made to the continuous simulation, and the most conservative volume must be used for water quantity control. Refer to **Section 6.1.2 Level of Service**.

3.2.4 Design Storm

3.2.4.1 General

Computer modelling requires the input of a design storm. This design storm is then used to generate runoff hydrographs to determine how an area will respond and perform. In Calgary, the IDF (Intensity-Duration-Frequency) curve is derived from Meteorological Service of Canada (formerly known as Atmospheric Environment Services) rainfall data taken from the airport. A Chicago distribution is then applied to formulate the synthetic design storm. The IDF curves and design storm is summarized below. A 100 year return period event is used in the design of the major system.

3.2.4.2 IDF Curve and Parameters

An IDF curve is a statistical description of the expected rainfall intensity for a given duration and storm frequency. In Calgary, the IDF curve is derived from Meteorological Service of Canada (MSC) rainfall data taken from the airport. Rainfall, which has been collected from 1947 to 1998 (48 years), has been analyzed using Gumbel distribution.

MSC IDF Curve

Table 3.2: Design Storm Hyetograph (mm)

Calgary Municipal Airport (MSC)
Period: 1947- 1998
Years of Record: 48 (4 years missing)
Gumbel Distribution

Time		Return Frequency					
Minutes	Hours	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
5	0.083	4.9	7.3	8.9	11	12.5	14
10	0.167	7.3	11.2	13.8	17.1	19.5	22
15	0.25	9	13.8	16.9	21	23.9	26.9
30	0.5	11	16.9	20.8	25.7	29.4	33
60	1	13.7	19.4	23.2	28	31.6	35.1
120	2	16.7	22.7	26.6	31.6	35.2	38.9
360	6	24.5	31.3	35.8	41.5	45.7	49.9
720	12	31.1	42	49.1	58.2	64.9	71.6
1440	24	37.2	51.2	60.4	72.1	80.8	89.4

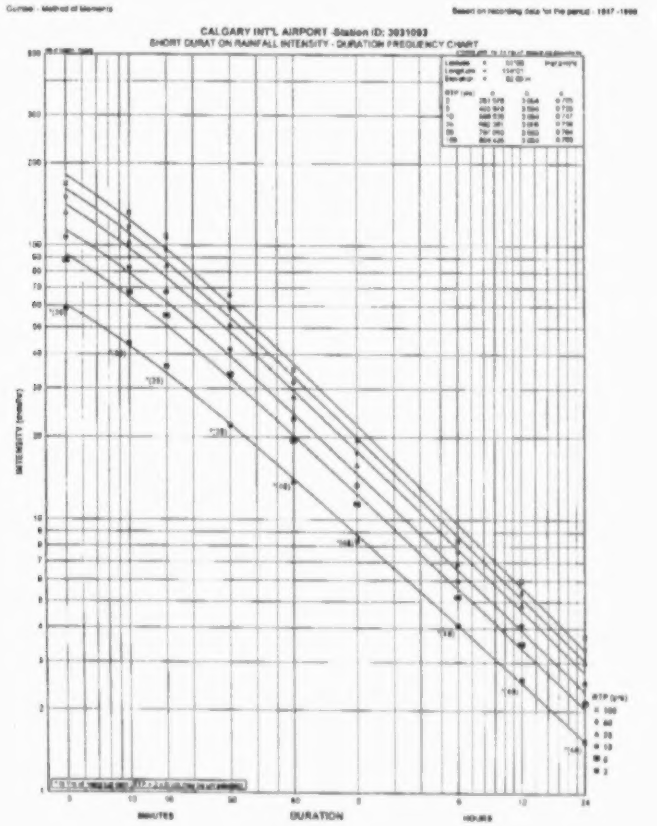


Figure 3.3: MSC IDF Curve for Calgary

The curves in Figure 3.3 were generated using the MSC hyetograph (Table 3.2) and the best fit IDF parameters (a, b, and c) derived (Table 3.3).

Table 3.3: IDF Parameters-Calgary Municipal Airport

Parameters	Return Frequency					
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
a	261.578	425.978	536.909	682.381	787.053	894.425
b	3.004	3.004	3.004	3.006	3.003	3.004
c	0.705	0.735	0.747	0.758	0.764	0.769

Parameters are derived for the formula:

$$I = a/(b + t)^c \qquad \textbf{Equation 3.5}$$

where : I = intensity (mm/hr)
t = time (minutes)
a,b,c = constants

Adjusted MSC IDF Curve and Parameters

Not all of the points fit the best-fit curves on Figure 3.3. In terms of design, the following durations are important for stormwater design (trap lows and stormwater ponds) in Calgary: 5 minute, 1 hour, 12 hour and 24 hour. Further analysis was undertaken to fine-tune the curves to these durations. **These adjusted values should be used for computer modelling purposes (see Tables 3.4 and 3.5).**

Table 3.4: Adjusted IDF Curve-Intensity Summary (mm/hr)

Calgary Municipal Airport (MSC)
Period: 1947- 1998
Years of Record: 48 (4 years missing)
Gumbel Distribution

Time		Return Frequency					
Minutes	Hours	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
5	0.083	58.8	87.6	106.8	132	150	168
60	1	13.7	19.4	23.2	28	31.6	35.1
720	12	2.59	3.50	4.09	4.85	5.41	5.97
1440	24	1.55	2.13	2.52	3.00	3.37	3.73

Table 3.5: Adjusted IDF Parameters

Parameters	Return Frequency					
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
a	243.0	353.5	429.1	522.6	594.9	663.1
b	2.71	2.29	2.16	1.96	1.94	1.87
c	0.695	0.703	0.707	0.709	0.711	0.712

a,b,c = constants (see Equation 3.5)

3.2.4.3 Chicago Distribution

Generally, IDF curves cannot be used directly for complex hydrograph computations. However, the Chicago Hydrograph Method can be used to create a rainfall distribution curve (or design storm) from the **adjusted** MSC IDF curve. The resulting design storm can then be used for hydrograph routing computations. Using Table 3.5, the Chicago distribution is used to generate the design storm for Calgary. As well, a time to peak (r) equal to 0.3 is used.

Time to peak (r) = 0.3

3.2.4.4 Storm Duration

It is important that the critical storm duration be identified properly.

i. The storm duration should be greater than twice the basin's time of concentration ($\geq 2t_c$). In general, a storm duration of 1 hour is suitable for most small urban areas. However, this should be confirmed at the time of modelling. Longer durations should be considered where there are backwater conditions from stormwater ponds.

ii. For the design of **trap low storage** in subdivisions or small areas, the following minimum is recommended:

- DDSWMM: 1 hour duration storm when using Horton's infiltration.
- SWMHYMO, OTTHYMO: 1 hour duration when using Horton's infiltration.
- SWMHYMO, OTTHYMO: 1 hour or 12 hour duration when using SCS (CN) method.

This information is based on the results of Wastewater & Drainage's study "Comparison Between DDSWMM and SWMHYMO" (2000).

iii. For the design of **storage volumes for stormwater ponds**, the following is recommended:

- SWMHYMO, OTTHYMO: 24 hour duration using Horton's infiltration or SCS (CN) method. (NOTE: Continuous modelling must also be used to determine the most conservative of the two volumes)

Please contact Wastewater & Drainage for further information.

3.2.5 Parameters

The amount and timing of runoff from a watershed is a function of several phenomena, which have varying degrees of importance. The runoff process includes the actual runoff and losses due to interception, infiltration, depression storage, abstraction, and evaporation. Some of these losses and other modelling parameters can have a significant impact on the amount of runoff if inappropriate values are used.

There are three popular methods used to determine runoff by taking into account hydrologic abstractions, soil types and antecedent moisture conditions. These include: Rational Method (runoff coefficient C), Soil Conservation Service (SCS) Method, and Horton Method. The SCS Method combines initial abstraction and infiltration for losses, while the Horton Method combines depression storage with infiltration. The Rational Method assumes that all of the abstractions are represented by a single coefficient, C.

Wastewater & Drainage is currently undertaking a sensitivity analysis of some of the modelling parameters as part of a calibration study; the results of the study will be made available as soon as the study is complete. In the interim, care should be taken when choosing modelling parameter values. Recommendations are made below:

3.2.5.1 Runoff Coefficient C

The runoff coefficient C is used in the Rational Method and is defined as the ratio of the average rate of rainfall on an area to the maximum rate of runoff. The runoff coefficient incorporates all of the hydrologic abstractions, soil types and antecedent moisture conditions. It is also important to note that the appropriate value of C depends on the magnitude of the storm; higher values may be required for extreme storm events.

Where runoff coefficients are required, The City of Calgary generally uses the following:

Description	Runoff Coefficient C
Residential	0.3
Industrial	0.4 to 0.75
Commercial, Downtown & Roadways	0.5 to 0.9

NOTE: An average weighted value of C should be used according to the size and type of area tributary to a given inlet.

For Drainage & Site Servicing Plans (DSSP), refer to **Section 4.2.2.3** for required runoff coefficients.

With higher return period storms, the value of the runoff coefficient increases. Table 3.6 illustrates the changes to C.

Table 3.6:
Typical Urban Runoff Coefficients for 5 to 10 year Return Period Storms

Description		Runoff Coefficient		
		Minimum	**Mean**	**Maximum**
Pavement	Asphalt or concrete	0.70	0.83	0.95
Roofs		0.70	0.83	0.95
Business	Downtown	0.70	0.83	0.95
	Neighbourhood	0.50	0.60	0.70
Industrial	Light	0.50	0.65	0.80
	Heavy	0.60	0.75	0.90
Residential	Single family urban	0.30	0.40	0.50
	Multiple, detached	0.40	0.50	0.60
	Multiple, attached	0.60	0.68	0.75
	Suburban	0.25	0.33	0.40
Apartments		0.50	0.60	0.70
Parks, Cemeteries		0.10	0.18	0.25
Playgrounds		0.20	0.28	0.35
Railroad Yards		0.20	0.28	0.35
Unimproved		0.10	0.20	0.30

Notes:

1. Values within the range given depend on the soil type if the watershed is significantly unpaved (sand is minimum, clay is maximum), slope, and on the nature of the development.
2. For storms having return periods of more than 10 years, increase the listed values as follows, up to a maximum coefficient of 0.95:
   25 year – add 10 percent
   50 year – add 20 percent
   100 year – add 25 percent
3. The coefficients listed are for unfrozen ground. Taken from RTAC (1982).

3.2.5.2 Depression Storage

If the intensity of the rainfall reaching the ground exceeds the infiltration capacity of the ground, the excess will begin to fill the small depressions on the ground surface. For impervious surfaces, this will occur almost immediately. Once these tiny depressions have filled, overland flow will start and contribute to the runoff. Table 3.7 lists suggested values for depression storage.

Table 3.7: Suggested Depression Storage Losses

Land Cover	Depression Storage (mm)	
	Range	Recommended
Impervious:		
Large paved areas	1.3 – 3.8	2.5
Roofs, flat	2.5 – 7.5	2.5
Roofs, sloped	1.2 – 2.5	1.2
Pervious :		
Lawn grass	2.0 – 12.5	7.5
Wooded areas	5.0 – 15.0	To be assessed

Source: Scheaffer et al, 1982

For Calgary, the following depression storage values are recommended:

Pervious Areas: 3.2 mm
Impervious Areas: 1.6 mm

3.2.5.3 Infiltration

Rainfall that reaches pervious ground surfaces will initially infiltrate into the upper layer of the soil. With periods of dry weather, the infiltration capacity of the soil can be quite large. However, this capacity will diminish gradually after the start of a rainstorm. The Horton Method and SCS (Soil Conservation Service) Method are two methods that are used to account for infiltration losses.

3.2.5.3.1 Horton Method

The Horton infiltration equation defines the infiltration capacity of the soil by using an initial infiltration rate that changes to a lower rate.

$$f = f_c + (f_o - f_c)e^{-k(t)}$$ **Equation 3.6: Horton Equation**

where : f = infiltration rate at time t (mm/hr)
f_c = final infiltration rate (mm/hr)
f_o = initial infiltration rate at the start of the storm (mm/hr)
k = decay rate (t^{-1})

For Calgary, the following Horton infiltration parameters are recommended:

- **f_o = 75.0 mm/hr**
- **f_c = 7.5 mm/hr**
- **k = 0.00115 s^{-1} (4.14 hr^{-1})**
- **t = time since initial infiltration rate**

Horton parameters applicable to specific areas are difficult to find. Figure 3.4 (Source: Stantec Consulting Ltd.) illustrates the Horton infiltration curve based on the soil intake data for Alberta soils and the recommended parameter values for f_o, f_c, and k. Based on these values, these parameters provide infiltration results similar to clay soil. Much of the soil in Calgary is clay based.

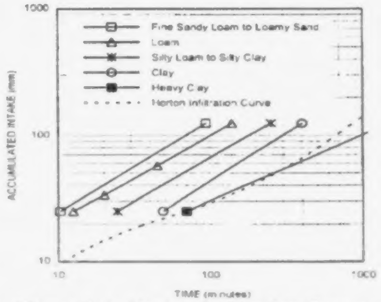


Figure 3.4: Horton Infiltration Curve using Alberta Soils and Recommended Values

3.2.5.3.2 Soil Conservation Service (SCS) Method

This method was originally developed by the Soil Conservation Service, U.S. Department of Agriculture to estimate agricultural runoff. Subsequently, the method has been widely applied to all types of hydrology problems, including urban drainage.

Runoff is calculated based on an equation that uses the total depth of rainfall, initial abstraction and CN (see equation 3.7). CN, or curve number can range from 0, which produces no runoff, to 100, which produces 100% runoff for a rainfall event. The runoff hydrograph is then generated by the unit hydrograph methodology.

$$Q = \frac{(P - I_a)^2}{P + S - I_a}$$ **Equation 3.7: SCS Equation**

where: P = total depth of rainfall (mm)
I_a = initial abstraction (mm)
S = soil storage (mm)

Initial abstraction (I_a) is the interception, infiltration and depression storage prior to runoff, and infiltration after runoff. I_a is typically equal to 0.2S based on an antecedent moisture condition II. With the modified SCS Method, I_a is equal to $S^{0.55}$.

Soil storage S is equal to:

$$S = [(25400/CN) - 254] \qquad \textbf{Equation 3.8}$$

where: CN = curve number

Curve number CN is described in the following **Section 3.2.5.4**.

3.2.5.4 Curve Number (CN)

Curve numbers CN are used in the SCS Method. The curve number is a function of soil type, ground cover and antecedent moisture conditions (AMC).

Four hydrological soil groups are defined:

A. (Low runoff potential) Soils having a high infiltration rate even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravel. Soils have a high rate of water transmission.

B. Soils having a moderate infiltration rate when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse texture. Soils have a moderate rate of water transmission.

C. Soils having a slow infiltration rate when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine texture. Soils have a slow rate of water transmission.

D. (High runoff potential) Soils having a very slow infiltration rate when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material. Soils have a very slow rate of water transmission.

Table 3.8 provides general information on CN values. CN values can range from 0, which produces no runoff, to 100, which produces 100% runoff for a rainfall event.

Recommended CN values for Calgary are 70 to 74. The average CN value to be used is 72. Use of lower CN values for urban modelling requires the approval of Wastewater & Drainage.

Table 3.8:
SCS Curve Numbers for Urban Areas

Cover Type and Hydrologic Condition	**Hydrologic Soil Group**			
	A	**B**	**C**	**D**
Fully developed urban areas (vegetation established)				
Open space: (lawns, parks, golf courses, cemeteries)				
Poor condition (grass cover < 50%)	68	79	86	89
Fair condition (grass cover 50% to 75%)	49	69	79	84
Good condition (grass cover >75%)	39	61	74	80
Impervious areas:				
Paved parking lots, roofs, driveways, etc.	98	98	98	98
(excluding right-of-way)				
Streets and roads:				
Paved; open ditches (including right-of-way)	83	89	92	93
Gravel (including right-of-way)	76	85	89	91
Dirt (including right-of-way)	72	82	87	89

Source: *Hydrology*, Engineering Handbook, USDA, Soil Conservation Service (1968)
NOTE: Assumes AMC II and I_a=0.2S

3.2.5.5 Imperviousness

Impermeable surfaces, such as pavement or rooftops, prevent the infiltration of water into the soil. Imperviousness is also an important parameter to consider in determining runoff. Table 3.9 lists some typical values applicable for Calgary.

Table 3.9:
Typical Imperviousness of Urban Catchments

Description	**% Imperviousness**
Single Family Residential with No Lanes:	
Overall	55
Front Yards and Streets	76
Rear Yards	25
Single Family Residential with Lanes:	
Overall	55
Front Yards and Streets	55
Rear Yards	55
Multi-Family	65
Light Commercial and Industrial	85
Commercial Malls with Large Parking Areas	95
Paved Surfaces and Roofs	100
Gravelled Roads, Lanes and Parking Areas	50
Major Road Right-of-Way	70

Source: Stantec Consulting Ltd.

Where imperviousness values are not provided, imperviousness can be estimated using air photo maps and weighted averaging.

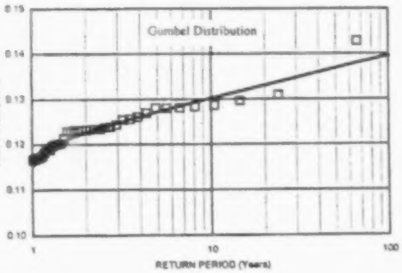
XIMP and TIMP are parameters used in the OTTHYMO and SWMHYMO models. XIMP is the ratio of the total area directly connected to the sewer system (ie. roof drains that drain to driveways and then to the street). TIMP is the ratio of total impervious area. **It is recommended that XIMP = TIMP for modelling purposes for Calgary.** Due to the accuracy of the models and the ingenuitive efforts of homeowners to directly connect downspouts to the roads and lanes, there is little reason at this time to distinguish these two values separately.

3.2.6 Statistical Analysis

Many hydrological processes are so complex that they can only be interpreted and explained in a probabilistic sense. Statistical analysis provides ways to reduce and summarize data, to determine underlying characteristics, or to make predictions.

Statistical (or frequency) analysis is required when determining storage volumes for stormwater ponds using continuous simulation. With continuous simulation, maximum yearly volumes are generated; **a statistical analysis must then be performed to determine the required 100 year volume.** Simply using the maximum storage volume generated over the time period is **not** correct.

Different distributions can be used in the regression analysis: Normal, Log-Normal, Person III, Log-Pearson III, Gumbel and Weibull. When choosing the best distribution for storage volume, the distribution with the best fit should be chosen. Best fit should be considered in terms of correlation and standard error.



3.3 Minor System Component Design

Typically, the minor system will quickly and efficiently remove rainstorm runoff below its design capacity. This section outlines the design criteria that applies to the components of the minor system for new developments.

3.3.1 Design Basis

i. The storm sewer pipe (minor) system must be designed as a **separate system** from the sanitary. Combined systems are not permitted.

ii. In general, the storm sewer must be designed to convey design flows when flowing full with the hydraulic grade line (HGL) at or below the crown of the pipe. Sewer pipes should not surcharge for design or 100 year flows unless previously approved by Wastewater & Drainage. **Surcharge to ground surface is strictly prohibited.**

iii. The minor system is to be designed according to the level of service stipulated in **Section 3.1.2.2**. All new developments should be designed using the Unit Area Release Rate Method.

3.3.2 Pipes

For additional information, also refer to City of Calgary "Design Guidelines for Subdivisions" and "Standard Specifications Sewer Construction".

3.3.2.1 Design Flow

i. The design flow of the minor system is to be determined according to the level of service stipulated in **Section 3.1.2.2**. All new developments should be designed using the Unit Area Release Rate Method.

ii. Where the Rational Method is permitted, the maximum inlet time at the upper end of the system is 10 minutes.

3.3.2.2 Capacity & Size

i. Manning's Formula shall be used to determine the gravity flow (capacity) and size of pipe required. Assume pipe is flowing full.

$$Q = \frac{1.0\,A\,R^{2/3}\,S_f^{1/2}}{n} \qquad \textbf{Equation 3.9}$$

where:
Q = discharge (capacity) (m^3/s)
R = hydraulic radius (A/P) (m)
A = cross-sectional area of pipe (m^2)
P = wetted perimeter (m)
S_f = friction gradient or slope of pipe
n = Manning's roughness coefficient

ii. Manning's n

• Concrete Pipe	n = 0.013
• PVC, Polyethylene (PE)	n = 0.011
• Ultrarib	n = 0.011*
• Corrugated Metal Pipe (std)	n = 0.017-0.030*

- Steel Pipe	n = 0.010-0.017*

* Values of Manning's n vary. Refer to the appropriate reference information. Approval from Wastewater & Drainage is required.

iii. Minimum Size

Minimum storm sewer diameters are as follows:

residential areas:	300 mm
commercial/industrial	375 mm
roof drains:	100 mm
weeping tile (main):	150 mm
weeping tile (service connection):	75 mm

See **Section 3.3.6.3** for more information on weeping tile.

3.3.2.3 Flow Velocities and Minimum Slope

i. The following **minimum** slopes must be used:

Table 3.10: Minimum Pipe Sizes

Size	Concrete Pipe n=0.013	PVC, PE Pipe n=0.011
	Minimum Slope (%)	Minimum Slope (%)
100 mm*	2.0	2.0
150 mm*	1.0	1.0
200 mm	0.8	0.6
250 mm	0.56	0.4
300 mm	0.44	0.32
375 mm	0.32	0.24
450 mm	0.26	0.18
525 mm	0.22	0.16
600 mm	0.18	0.12
675 mm	0.15	0.11
750 mm	0.13	0.10
≥900 mm	0.10	0.10

* where permitted and approved by Wastewater & Drainage (DSSPs)

ii. Storm sewers must be designed to provide a **minimum** velocity of 0.90 m/s when flowing full.

iii. Where velocities in excess of 3.0 m/s are proposed, provision shall be made to protect against displacement of sewers by sudden jarring or movement. Supercritical flow should not occur on steep grades, unless provisions are made in the design to address structural stability and durability concerns. In general, anchors are required on pipes where pipe slope is ≥ 33% or as requested by Wastewater & Drainage.

3.3.2.4 Cover

For public storm sewers, the **minimum** depth of cover from pipe crown to finished road grade is 1.2 m. A cover depth greater than 1.2 m is preferable.

For private property connections (Drainage & Site Servicing Plans), the **minimum** depth of cover from pipe crown to finished grade is 1.0 m. A greater cover depth is preferable for frost protection.

3.3.2.5 Pipe Material, Strength & Bedding

i. All pipe shall conform to and be installed as per City of Calgary "Standard Specifications Sewer Construction".

ii. All concrete pipes and appurtenances shall be manufactured using Type 50 alkali resistant cement. Concrete pipes over 300 mm in diameter shall be reinforced concrete pipe.

iii. All pipe is to be rubber gasketed, except when approved otherwise by Wastewater & Drainage.

iv. PVC DR35 may be used for pipe diameters ≤1050 mm, otherwise concrete pipe must be used (see City of Calgary "Standard Specifications Sewer Construction"). Use of other pipe materials and/or sizes require the approval of Wastewater & Drainage prior to installation.

v. Typically, PVC DR35 is used for storm connections for Drainage & Site Servicing Plans (DSSPs). However, Ultrarib may also be used. Use of any other plastic pipe materials must be approved by Plumbing Services and Wastewater & Drainage. The designer/consultant is responsible for ensuring the proper class of pipe and bedding is installed. See City of Calgary "Standard Specifications Sewer Construction" for more information.

vi. For DSSPs, cast iron or an approved equivalent is required under buildings, ramps, overhangs and underdrives.

vii. All pipe bedding shall conform to and be installed as per City of Calgary "Standard Specifications Sewer Construction".

viii. **Unless specified otherwise, normal bedding Class C shall be used for concrete pipe.** Refer to City of Calgary "Standard Specifications Sewer Construction". Selection of other bedding or other methods (tunnelling, jacking, etc.) requires the approval of Wastewater & Drainage.

ix. **Unless specified otherwise, normal pipe embedment material classification for PVC pipe shall be Class III with a minimum compaction of 90% Standard Proctor Density.**

x. For selection of concrete pipe class for class C bedding, refer to City of Calgary "Design Guidelines for Subdivisions". The maximum allowable trench width should not be exceeded. In the case of two utilities placed in the same trench or where the trench exceeds the maximum allowable, then pipe strength must be increased or the bedding improved.

3.3.2.6 Concrete Encasement

Concrete encasement is **not** required for flexible pipe.

For concrete pipe:

i. Concrete encasement is required for maintenance purposes where access is limited.
ii. Concrete encasement is not required in a PUL, large open area, or where a wide easement is provided.
iii. The length of encasement is site-specific and must be approved by Wastewater & Drainage. Generally, only the affected pipe length would require encasement, not necessarily from manhole to manhole.

3.3.2.7 Drainage Length

i. The normal length of run for **streets** before sewer interception shall be 150 m. Where grades exceed 1%, this distance may be extended to a maximum length of 300 m. Invert crossings (crossfalls) are not permitted.

ii. The length of drainage in a lane is to be minimized. Any drainage length over 175 m is subject to review by Wastewater & Drainage.

The **maximum** length of drainage in lanes shall be 350 m, cumulative to any one catchbasin(s).

3.3.2.8 Curved Sewers

Curved (radiused) sewers and bends are permitted to conform to curved street layouts and to offer hydraulic improvement. The required minimum grade for sewers on a curve shall be 50% greater than the minimum grade required for a straight run of sewer. See also City of Calgary "Design Guidelines for Subdivisions" for minimum radii of curvature and permitted joint deflections.

3.3.2.9 Oversize

Any storm system or part of a system must be designed to serve the area within the subdivision development boundary **plus** any area tributary to the system, as outlined in the storm catchment maps. When The City of Calgary requires a storm sewer to be larger than necessary to serve an additional area not owned or controlled by the developer, the City shall pay the developer the additional cost of oversize. See City of Calgary "Design Guidelines for Subdivisions" for more information.

When oversize is required to service upstream areas, preliminary design drawings and profiles must be submitted and approved by Wastewater & Drainage prior to release of underground construction permission.

3.3.2.10 Hydraulics

i. In general, the storm sewer must be designed to convey design flows when flowing full with the hydraulic grade line (HGL) at or below the crown of the pipe. Sewer Pipes should not surcharge for design or 100 year flows unless previously approved by Wastewater & Drainage. **Surcharge to ground surface is strictly prohibited.** Inlet Control Devices are required to control flows into the pipe system. See **Section 3.3.5** for more information.

ii. The storm sewer must be designed to account for hydraulic losses due to bends, junctions, transitions, etc. See **Section 5.0 Hydraulics** for further information.

iii. Hydraulic grade line (HGL) calculations are required where surcharge conditions may occur due to backwater affects from stormwater ponds, where hydraulics present a potential problem, or as requested by Wastewater & Drainage.

3.3.2.11 Alignment & Easements

See City of Calgary "Design Guidelines for Subdivisions" for alignment and easement requirements.

3.3.2.12 Service Connections

See City of Calgary "Design Guidelines for Subdivisions", "Standard Specifications Sewer Construction", and "Design Guidelines for Development Permits, Mechanical Site Plans and Solid Waste Services Plans" for service connection and alignment requirements. See **Section 4.4.1 Service Connections** for additional information on Drainage & Site Servicing Plans.

3.3.3 Manholes

For additional information, also refer to City of Calgary "Standard Specifications Sewer Construction".

3.3.3.1 Location

Transitions in size, grade or direction of sewer pipes are to be accomplished by means of manholes, except in the case of curved sewers.

3.3.3.2 Types

i. For two pipes 600 mm in diameter or smaller, use a Type 5A manhole, except where a 3 or 4 way junction occurs. Where a 3 or 4 way junction occurs, a Type 1 or 1-S manhole may be required depending on pipe sizes and the vertical separation.

ii. For pipe 675 mm in diameter of larger, use a Type 1 manhole, or a Type 1-S manhole.

iii. Pre-cast T-riser manholes will be accepted for 1200 mm diameter or larger trunks where there is no change in pipe size, grade, or direction. T-riser manholes may be required at pre-fabricated bends.

3.3.3.3 Material

i. All manholes shall conform to and be installed as per City of Calgary "Standard Specifications Sewer Construction".

ii. All manholes and appurtenances shall be manufactured using Type 50 alkali resistant cement.

3.3.3.4 Spacing

The maximum distance between manholes shall be 185 m. In all cases, a manhole is required at the upper end of a sewer for maintenance purposes.

Modifications to manhole spacing may be required where sewers are curved.

3.3.3.5 Drops

i. At manholes where changes in pipe diameter occur, the elevation of the crowns should be kept continuous to maintain the energy gradient.

ii. Where no change in pipe diameter occurs, a minimum drop of 30 mm is required in a through manhole.

iii. Where no change in pipe diameter occurs, a minimum drop of 60 mm is required in a bend.

iv. In general, large drops are discouraged due to hydraulic considerations. For drops greater than 1 m, a specially designed drop manhole may be required to address hydraulic requirements due to the elevation change.

3.3.3.6 Benching

See City of Calgary " Standard Specifications Sewer Construction " for benching requirements (file 452-1003-007) and **Section 5.0 Hydraulic Design**. Where benching is required for hydraulic concerns, details must be shown on the construction drawings.

3.3.3.7 Junctions and Bends

i. When connecting laterals to large trunks, it may be advantageous to build a manhole on the lateral immediately adjacent to the trunk with a direct connection from the manhole to the trunk.

ii. Where 2 large diameter (greater than 750 mm) incoming laterals enter a manhole, the manhole must be hydraulically designed. See **Section 5.0 Hydraulic Design**. The use of bends and curved pipe, etc. should also be considered.

iii. Bends should be 90^0 or less. A bend is defined as a deflection of the horizontal alignment between incoming and outgoing sewers.

3.3.3.8 Hydraulics

Sufficient change in sewer invert elevation must be provided across manholes and at junctions and bends to account for energy losses due to flow transitions, turbulence and impingement. See **Section 5.0 Hydraulics** for further information.

3.3.3.9 Service Connections

See City of Calgary "Design Guidelines for Subdivisions" and "Standard Specifications Sewer Construction" for service connection requirements. See **Section 4.4.1 Service Connections** for requirements for Drainage & Site Servicing Plans.

3.3.4 Catchbasins

For additional information, also refer to City of Calgary "Standard Specifications Sewer Construction".

3.3.4.1 Location

i. Catchbasins (CBs) are to be installed to intercept all overland flows, including back lanes and gutters/swales.

ii. Catchbasins are required at trap lows or sags in the road. The requirement for catchbasins in parks (MRs, ERs, etc.) is at the discretion of Park Development & Operations.

iii. For roadway intersections with a continuous grade around a corner, catchbasins are to be located at the EC or BC of the curb radii on the uphill side of the curb return.

3.3.4.2 Types

i. There are 4 types of catchbasins:
   - Type C catchbasin with storm back (previously Type K)
   - Type K2 catchbasin for rolled curb and gutter
   - Type K3 catchbasin
   - Grated Top manhole

   Refer to City of Calgary "Standard Specifications Sewer Construction" for further information.

ii. Catchbasins must be twinned (two CBs built side by side and interconnected) in trap lows, where there is a large drainage area (> 1.0 ha), or where a large amount of water may accumulate after bypassing upstream catchbasins situated on very long steep streets. Type C catchbasins with storm backs must be used.

iii. **Where conflicts with driveways occur**, there must be a minimum of one Type C CB in a trap low; K2 CBs will be accepted for the other catchbasin(s).

If an existing CB is located within a proposed driveway, the existing CB can be converted to a K2 and a new CB must be installed on the curb just upstream of the new driveway. The new CB shall be connected to the converted existing CB.

iv. Type K2 and/or C catchbasins may be used on continuous grades, depending on curb type.

v. Interconnected single catchbasins may be used when capacity restrictions prevent the use of multiple catchbasins or catchbasin leads. When interconnected CBs are used, the downstream CB requires a double barrel. Use of interconnected CBs should be kept to a minimum.

vi. A grated top manhole at the upper end of a lateral may be required, plus a lane-type CB as per City Standards, for storm sewer laterals extended to drain low lanes.

vii. For Drainage & Site Servicing Plans, grated top manholes should be used in place of catchbasins when:

- The depth from the rim to the pipe invert exceeds 2.3 m
- The total sum of incoming pipe diameters is > 600 mm.

In both of these conditions, the use of a manhole is required instead of a catchbasin barrel.

3.3.4.3 Material

i. All catchbasins shall conform to and be installed as per City of Calgary "Standard Specifications Sewer Construction".

ii. All concrete pipes and appurtenances shall be manufactured using Type 50 alkali resistant cement.

3.3.4.4 Capacity

Two conditions of flow occur with catchbasins: flows along a continuous grade and flows under ponding (trap low) conditions. Catchbasins on a continuous grade, or flow-by conditions, will capture only a portion of the flow. The balance of flow will bypass the catchbasin. Based on testing done by Townsend and Moss (1980) and Wilson (1983), Stantec Consulting Ltd. has developed capture curves for four types of City of Calgary catchbasins (K2, K3, C, and Twin C) for flow-by and ponding conditions. The following information should be used to determine whether Inlet Control Devices (ICDs) are required and capture into the pipe system. There is no capture information currently available for Grated Top manholes. When required, the consultant is responsible for determining an adequate capture curve for grated top manholes.

Flow-by Conditions

Table 3.11: Capture Rating Data for City of Calgary Catchbasins under Flow-by Conditions

K2 Catchbasin		K3 Catchbasin		C Catchbasin	
Street Flow (L/s)	**Capture (L/s)**	**Street Flow (L/s)**	**Capture (L/s)**	**Street Flow (L/s)**	**Capture (L/s)**
0	0	0	0	0	0
5	5	6	6	9	9
10	7.1	10	7.6	15	12.7
25	10.9	25	10.8	25	16.5
50	16	50	15.5	50	23
75	20	75	19.6	75	28.2
100	23.2	100	23.5	100	32.8
200	33.1	200	35.2	200	48
300	38.8	300	42.2	300	61.1
500	46.1	500	51	500	79.3
1000	56	1000	63	1000	104

Source: Stantec Consulting Ltd.

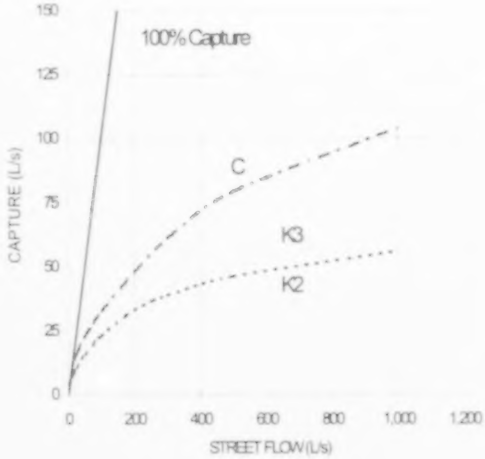


Figure 3.5: Capture Rating Curve for City of Calgary Catchbasins under Flow-by Conditions

Ponding Conditions

Table 3.12: Capture Rating Data for City of Calgary Catchbasins under Ponding Conditions

Ponding Depth (m)	Capture Rate (L/s)			
	K2	K3	C	Twin C
0.0	0.0	0.0	0.0	0.0
0.1	48.3	77.5	110.0	219.3
0.2	83.8	109.6	150.7	227.8
0.3	108.3	134.3	155.5	235.9
0.4	128.3	155.1	160.1	243.7
0.5	145.5	164.6	164.6	250.7

Source: Stantec Consulting Ltd.

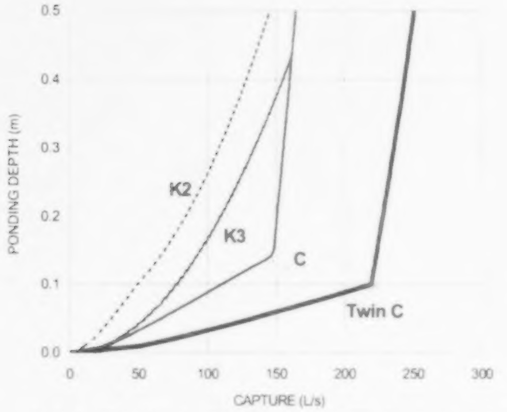


Figure 3.6: Capture Rating Curves for City of Calgary Catchbasins under Ponding Conditions

Inlet Control Devices (ICDs) are required in catchbasins to prevent surcharge of the pipe system during the design and 100 year flows. Refer to **Section 3.3.5 Inlet Control Devices** for more information.

3.3.4.5 Spacing

i. Catchbasin spacing shall range from 90 m to 150 m, with closer spacing required for flat grades and at all corners where storm sewers exist, except in the case of a high corner (ie. drainage away from corner in both directions). See **Section 3.3.2.7** also.

ii. The maximum length of drainage in lanes shall be 350 m. The length of drainage in a lane is to be minimized where possible. Lengths over 175 m are subject to review by Wastewater & Drainage.

iii. Where CBs are located in lanes, it is necessary to compact utility trenches and pave 23 m in each direction from the catchbasin. Trap lows in lanes should be avoided when possible.

3.3.4.6 Lead Sizes & Slopes

i. All catchbasins must be connected to a manhole, not directly to the main.

ii. Lead sizes are as follows:

Single CB	250 mm lead
Twin CB	300 mm lead (one common lead)
Interconnected CB	300 mm lead (one common lead)

iii. The length of a catchbasin lead should not exceed 30m.

iv. A minimum slope of 2% is required on all leads.

v. For Drainage & Site Servicing Plans, the **minimum** lead size for an area drain CB is 250 mm diameter. Exceptions are as follows:

- Where routes require cast iron or equivalent PVC pipe, smaller pipe sizes will be accepted,
- Where the pipe is directly involved in a stormwater retention system or is upstream of a retention system, a minimum size of 150 mm diameter is acceptable.
- Where the public mains are less than 525 mm diameter, pipe sizes from 150 mm to 250 mm diameter will be considered.

All lead sizes for DSSP area drains must be approved by Wastewater & Drainage.

3.3.4.7 Hydraulics

Sewer pipes should not surcharge for design or 100 year flows unless previously approved by Wastewater & Drainage. Inlet Control Devices are required in catchbasins to prevent surcharge of the pipe system during these rain events. Refer to **Section 3.3.5 Inlet Control Devices** for more information.

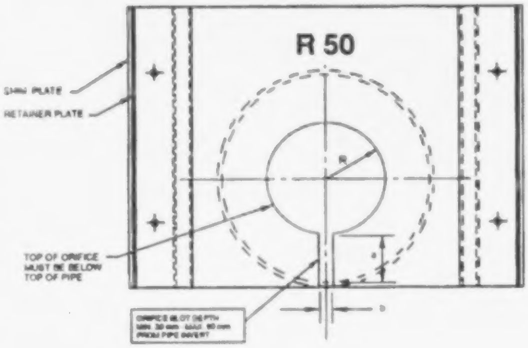
3.3.5 Inlet Control Devices

3.3.5.1 Types

Inlet Control Devices (ICDs) are required to prevent surcharge of the pipe system during the design and 100 year flows. The ICDs are plates installed inside the catchbasin over the inlet of the lead. Refer to City of

Calgary "Standard Specifications Sewer Construction" for more information.

The City of Calgary has four standard ICDs that should be used to control flows into the storm sewer: R30, R50, R70 and R100.


R 50
SHIM PLATE
RETAINER PLATE
R
a
b
TOP OF ORIFICE MUST BE BELOW TOP OF PIPE
ORIFICE SLOT DEPTH MIN. 30 mm MAX. 50 mm FROM PIPE INVERT

3.3.5.2 Discharge

Discharge (L/s) of the ICDs is determined for each size based on the City of Calgary study "ICD Testing Results" (1995). The orifice equation was utilized along with slot dimensions a=30mm and b= 30 mm.

• R30	Q=17.1/H
• R50	Q=30.05/H
• R70	Q=49.4/H
• R100	Q=89.8/H

For trap lows, rating curves for the ICDs were developed using (H = z + depth of ponding on the road). z is defined as the depth from the centre of the orifice to the top of the catchbasin at surface; z equal to 1.176 m (based on the height of one catchbasin barrel) was used in the following table. Refer to Stantec Consulting Ltd.'s "Application of DDSWMM with EXTRAN Linkage" (1996) for further information.

Table 3.13: Capture Rating Data for Standard City of Calgary Inlet Control Devices

Ponding Depth (m)	Capture Rate (L/s)			
	R30	R50	R70	R100
0.0	18.1	31.5	51.2	91.8
0.1	18.9	32.9	53.6	96.1
0.2	19.6	34.2	55.8	100.2
0.3	20.4	35.5	58.0	104.2
0.4	21.1	36.8	60.0	108.0
0.5	21.7	38.0	62.0	111.7

Source: Stantec Consulting Ltd.

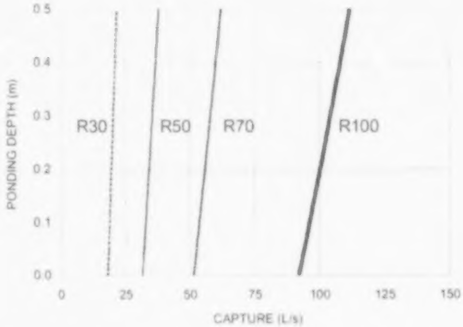


Figure 3.7: Capture Rating Curves for Standard City of Calgary Inlet Control Devices

The consultant should minimize the use of R30 ICDs where possible to reduce the potential for plugging.

3.3.6 Weeping Tile (Foundation Drain)

Weeping tile, or foundation drain, is typically used to provide protection of foundations due to high water tables. Three types of systems are available: direct connection to the storm sewer, sump pump, and a three pipe system.

3.3.6.1 Types

Storm Connection

All weeping tile is required to tie to the storm sewer by gravity. Connection to the sanitary sewer is **not** permitted.

Sump Pump

There are some circumstances where connection to the storm sewer is not possible or recommended:

- Infill housing where storm sewer is available, but footing elevations must be set low to conform to grades of adjacent developments, therefore making gravity drainage impossible,
- Infill housing where storm sewer is unavailable,
- Existing lots that experience storm sewer backup,
- Lots where the hydraulic grade line (HGL) is sufficiently high to cause potential storm sewer backup. This includes lots or areas in a floodplain.

In these situations, pumping water from a sump (ie. sump pump) is recommended with discharge to the ground surface being preferable.

Three Pipe System

When the HGL is sufficiently high and the impact affects a significant area, then a separate pipe system (third pipe) that carries only foundation drainage should be considered. Wastewater & Drainage should be contacted. Although this is not necessarily the recommended solution, the three pipe system provides good and virtually fool-proof drainage to basements and allows the storm sewer to surcharge with virtually no consequences. However, due to the additional pipe system, there is the added potential for cross connections between the sanitary, storm and foundation drain systems.

3.3.6.2 Requirements

Residential (R1, R2, R2A), Multi-Family

i. All weeping tile is to be connected to the storm sewer; connection to the sanitary sewer is not permitted.

ii. Weeping tile is required on lots:

- where the lowest top of footing (LTF) is **less than 2.1 m** above the seasonally adjusted water table (see **Section 3.3.6.8**),
- on fill of 2 m or greater, or
- requiring bearing certificates

iii. Where weeping tile is required for walkout basement lots, the weeping tile must be designed and installed to provide total basement seepage protection.

Infill Housing

a) where storm sewer is available:

   i. Weeping tile is required to tie to the storm sewer; connection to the sanitary sewer is not permitted.

   ii. Weeping tile is required unless a qualified soil consultant has determined otherwise. The consultant shall use the criteria set out in **Section 3.3.6.8**. A letter with the appropriate elevations (in metric geodetic) and information will be required by Wastewater & Drainage.

   iii. A sump pump is required to collect weeping tile flow and discharge it to a storm sewer by gravity when normal weeping tile drainage by gravity is not possible. This may occur where the footing must be set low to conform to grades of adjacent developments.

   iv. The gravel blanket below the footing and basement slab is **NOT** considered a substitute for weeping tile around the building footing.

b) where storm sewer is NOT available:

i. Weeping tile is required unless a qualified soil consultant has determined otherwise. The consultant shall use the criteria set out in **Section 3.3.6.8**. A letter with the appropriate elevations (in metric geodetic) and information will be required by Wastewater & Drainage.

ii. If the consultant concludes that weeping tile is required, then the weeping tile must be connected to a sump pump that discharges the flow onto the lot such that it drains away from the house.

c) floodplain areas:

All developments within a designated floodplain area require weeping tile in conjunction with a sump pump which discharges the flow to surface, whether storm sewer is available or not. See Section **3.5 Floodplain Requirements** for further information.

3.3.6.3 Size & Slope

The **minimum** diameter for weeping tile connections is 75 mm.

Weeping tile must be designed to provide a **minimum** velocity of 0.60 m/s when flowing full.

3.3.6.4 Cover

Adequate cover is required for frost protection. This should be 1.2 m where possible.

3.3.6.5 Backwater Valves

Backwater valves, or backflow prevention devices, are required on all weeping tile systems to minimize backup of stormwater. P traps are required to minimize backup of sewer gas.

Flodrains are not permitted where a plumbing arrangement may introduce groundwater to a sanitary sewer system.

3.3.6.6 Hydraulics

Weeping tile must **not** surcharge.

Where storm sewer surcharge conditions may occur, the lowest top of footing (LTF) elevation must be a minimum of 0.3 m above the

HGL. In these cases, the HGLs must be shown on the Building Grade Plan, at the approximate manhole location, or on the lot information.

3.3.6.7 Service Connections

See City of Calgary "Design Guidelines for Subdivisions" and "Standard Specifications Sewer Construction" for service connection requirements.

3.3.6.8 Water Table Requirements

Groundwater elevations are required to determine the need for weeping tile. If no water table readings are included, weeping tile must be installed. Requirements are as follows:

- The highest anticipated groundwater table elevation for an area must be determined by adequate test wells.
- Test holes are to be spaced on an approximate 150 m grid with modifications as required to suit the particular subdivision. A set of test hole logs should accompany the plan, listing soil sulphate content and water level readings. **Subdivisions require successive readings for a period of 6 months at one month intervals. Infill lots require a minimum of two test hole readings obtained one month apart.**

TEST HOLE NO	SOIL SULPHATE CONTENT %	GROUND ELEV AT HOLE	BOTTOM OF HOLE ELEVATION	WATER LEVEL READINGS													TEST HOLE NO
				DATE													
				CORRECTION													
				AS READ / CORRECTED													
				AS READ / CORRECTED													
				AS READ / CORRECTED													
				AS READ / CORRECTED													
				AS READ / CORRECTED													
				AS READ / CORRECTED													
				AS READ / CORRECTED													
				AS READ / CORRECTED													
				AS READ / CORRECTED													
				AS READ / CORRECTED													
				AS READ / CORRECTED													
				AS READ / CORRECTED													

NOTE HIGHEST CORRECTED WATER LEVEL SHOULD BE CIRCLED FOR EACH TEST HOLE

Table 3.14: Test Hole Data

- Water table readings must be seasonally adjusted using the following curve:

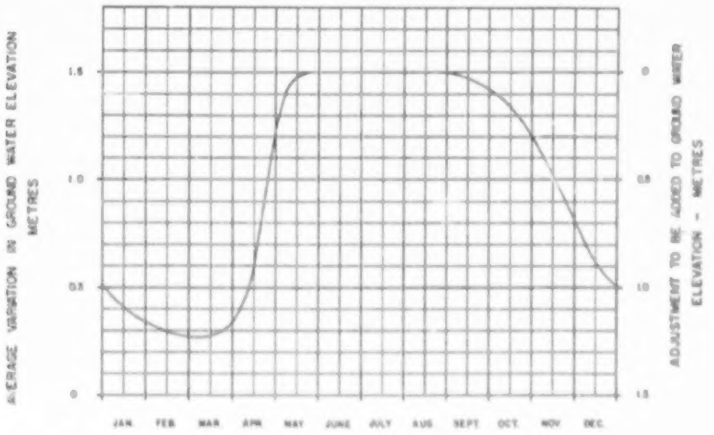


Figure 3.8: Groundwater Adjustments

- Weeping tile is required where the lowest top of footing (LTF) is **less than 2.1 m** above the seasonally adjusted water table.
- Subdivision construction drawings must include the following information:
  - ➢ Location of test holes
  - ➢ Test hole information and readings
  - ➢ Contours of the highest seasonally adjusted water table
  - ➢ Proposed LTF of each lot
  - ➢ Identification of lots requiring weeping tile (legend)

3.3.7 Outfalls

3.3.7.1 General

i. Structural and hydraulic details of storm outfalls are to be submitted to Wastewater & Drainage for approval.

ii. Provincial approval and permits are required for all outfalls discharging into watercourses (ie. Bow River, Elbow River, Nose Creek, Fish Creek, etc.)

iii. All outfalls and appurtenances shall be manufactured using Type 50 alkali resistant cement.

iv. The minimum distance from the point of discharge to the nearest dwelling is to be 150 m, if discharge is to an open ditch.

3.3.7.2 Hydraulics

i. In order to minimize erosion, outalls are to extend to the bottom of drainage courses or to the edge of streams. **Discharge onto steep slopes will not be accepted.**

ii. Hydraulic requirements of the outfall must be considered. Exit velocities must not damage or erode watercourses. Suitable baffles, aprons and rip-rap must be considered. Hydraulic losses must be taken into account.

iii. Outfalls should discharge at or above the normal water elevation of the watercourse to prevent problems due to freeze-thaw and hydraulic jumps (that result due to high tailwater conditions).

3.3.7.3 Maintenance

i. Access to the outfall must be provided for maintenance purposes.

ii. A skimming manhole, or approved equivalent, must be provided upstream of the outfall to remove oil and chemical spills. The skimming manhole must be easily accessible for tandem axle maintenance vehicles. A skimming manhole will not be required if the discharge to an outfall is directly from a stormwater wet pond or wetland.

3.3.7.4 Safety & Aesthetics

i. All outfalls shall be constructed with safety provisions to prevent the entrance of children or other unauthorized persons. A grate with vertical bars shall be installed with means for locking. Provision must be made for opening or removing the grate for cleaning purposes. Grates should be designed to break away under extreme hydraulic loads due to blockage.

ii. Corrosion-resistant guardrails shall be installed along concrete headwalls and wingwalls.

iii. Outfalls, which are often located in parks, ravines or along the river banks, should be made as safe and attractive as possible. Aesthetic treatment or concealment is to be part of the overall design. Bushhammered or exposed aggregate concrete is recommended. River Valleys Committee may be contacted for recommendations.

3.3.8 Culverts

All culverts are to be approved by Wastewater & Drainage. Submission of hydraulic design calculations to identify design flow conditions and inlet and outlet head conditions may be required. Energy dissipation and erosion control measures should be considered in the design. Clay plugs are also required

3.3.9 Pumping

In general, stormwater pumping is not acceptable; storm systems must drain by gravity. Contact Wastewater & Drainage for more information.

3.4 Major System Component Design

The major drainage system conveys runoff from the extreme rainfall events that are in excess of the minor underground system. In Calgary, the major system must be designed for the 100 year return period storm. Components of the major system facilitate the safe conveyance of these overland flows to appropriate safe points of escape or storage. This section outlines the design criteria that apply to the components of the major system. Overland flows are also regulated by the City of Calgary Drainage Bylaw 26M98.

3.4.1 Roof Leaders

The most common means of accommodating roof drainage is to direct it to ground that is graded away from the building. Discharge of roof leaders should be onto grassed or pervious areas to help reduce the volume of runoff. Direct connection of roof leaders to weeping tile or storm sewer is prohibited. Drainage of runoff via downspouts, eavestroughing, piping or other means must not discharge within 2 m of a street (see Bylaw 26M98 for further information).

3.4.2 Lot Grading & Drainage

Carefully designed and controlled lot grading is an important component of the Major System and good stormwater management.

3.4.2.1 Types

There are typically three types of lots: split drainage, back-to-front, and front-to-back. Split drainage is the most frequent type of lot drainage in Calgary and is the preferable drainage arrangement. Front-to-back drainage is not recommended.

3.4.2.2 Requirements

i. Grades adjacent to new buildings should be sufficient to allow for settlement of fill and maintenance of positive drainage away from the building. The finished grade elevations at buildings should be established by following Canada Mortgage and Housing Guidelines "Finished Grade Elevation at the Building for Residential Lots". The slope of the area directly adjacent to the building is to be a minimum of 10% for a distance of 2.0 m or to the property line. Slopes outside this perimeter should be maintained at 1.5% to 2.0% to the property boundary.

ii. An overall minimum slope of 2% should be established on all lots. The minimum grade should normally be exceeded if topography allows.

iii. All property elevations must be shown on the Building Grade Plan.

iv. Side yard elevations for lots adjacent to trap lows must be set a **minimum** of 0.2 m above the spill elevation or 100 year elevation, whichever is greater.

v. For DSSP lots, all pertinent grading must be shown. This includes berms, trap low ponding areas, ponds, and overland escape routes. All buildings on the lot must be protected from flooding.

3.4.2.3 MGs/RMGs/TOSs/Restrictive Covenants

MGs/RMGs

i. Minimum building opening elevations (MGs) must be specified for all lots adjacent to trap lows. Building openings refer to window wells, garage doors and door entrances. These elevations are to be specified on the building grade plan (BGP) for all affected lots.

ii. Where the overland escape route is via a **public road**, opening elevation MGs are to be set a **minimum** of 0.3 m above the spill elevation ($Elev_{spill}$) or the 100 year elevation ($Elev_{100}$), whichever is higher. It is preferable that MGs be set 0.4 m above the spill elevation or the 100 year elevation; this permits flexibility in the design should upstream trap low ponding conditions change. Trap lows in lanes must adhere to the same minimum opening elevations.

iii. Where the overland escape route is via a **PUL, MR or utility right-of-way**, opening elevation MGs are to be set a **minimum** of 0.5 m above the spill elevation ($Elev_{spill}$) or the 100 year elevation ($Elev_{100}$), whichever is higher. Trap lows in lanes must adhere to the same minimum opening elevations. Deviations due to extenuating circumstances require the approval of Wastewater & Drainage.

iv. For Drainage & Site Servicing Plans, top of slab elevations (TOS) for buildings are to be set a **minimum** of 0.3 m above the spill elevation ($Elev_{spill}$) or the 100 year elevation ($Elev_{100}$), whichever is higher.

v. Additional designations of (f), (s), (r), and (g) should be used when there is more than one trap low adjacent to a lot. (f), (s), (r), and (g) designate front, side, rear, and garage opening elevations respectively.

Restrictive Covenants

i. Restrictive covenants are required when the spill depth of the trap low is > 0.3 m. Restrictive covenants require the registering of a drainage easement on affected lots.

ii. When a restrictive covenant is required, the minimum opening elevation shall be identified as RMG. R designates the requirement for a restrictive covenant.

3.4.3 Roads

Overland flows will likely fill local roads during the 100 year event. The following criteria should be followed:

i. There must be continuity of overland flows between adjacent developments. Unless overland spill has been specifically designed in a downstream development, overland flow must be stored within the subdivision phase boundary. Approval from Wastewater & Drainage is required where overland flows spill from development to development. Master Drainage Plan or Staged Master Drainage Plan reports should indicate acceptability of, and degree of, permitted overland flows.

ii. Arterial roads must have at least two lanes which are not inundated with overland flow. Where overland flow crosses an arterial road, the depth of flow should be less than 0.05m.

iii. Collector roads must have at least one lane which is not inundated with overland flow. Where overland flow crosses a collector road, the depth of flow should be less than 0.10 m.

iv. The maximum depth of flow at the curbside gutter should be no more than 0.30 m. Depths less than 0.20 m are preferable (just above or at curb height).

v. **Standing water at low points (trap lows) should not exceed 0.5 m in depth. Where feasible, the maximum depth of ponding in trap lows shall be 0.3 m.** Ponding on arterial roads should be avoided where possible; approval for ponding is required by Wastewater & Drainage in these situations. Ponding on collector roads should be kept to a minimum where possible.

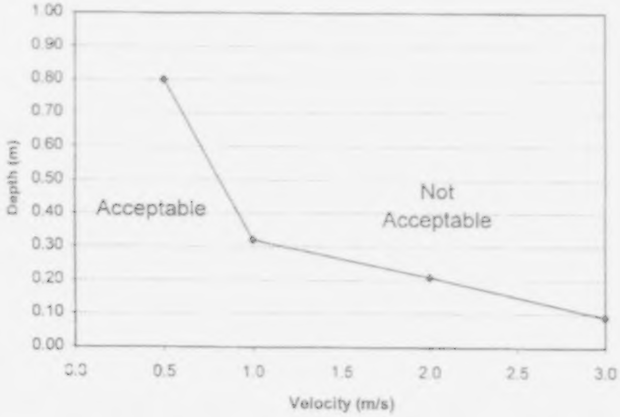
vi. The velocities and depths of flow for the major drainage system should not exceed the values outlined in Table 3.15. Values outside of these limits must be approved by Wastewater & Drainage.

Table 3.15:
Permissible Depths for Submerged Objects

Water Velocity (m/s)	Permissible Depth (m)
0.5	0.80
1.0	0.32
2.0	0.21
3.0	0.09

Note: Based on 20-kg child and concrete-lined channels.
Larger persons may be able to withstand deeper flows
Source: Stormwater Management Guidelines for the Province of Alberta (1999)

Figure 3.9: Permissible Depths and Velocities



vii. Q, v and d (flow, velocity and depth) must be indicated for all critical locations: into trap lows, out of trap lows, concrete swales with large drainage areas, etc., to ensure depth-velocity requirements are met. Modelled flows may be pro-rated on an aerial basis.

3.4.4 Trap Lows (Surface Ponding)

Trap lows are sags or depressions that are located along roads or in parks. Trap lows are part of the major overland system and provide stormwater storage areas local to the area where the flows are generated. Temporary storage is created during the major rainfall events through the use of ICDs. Trap lows are a vital component of the major system in that they minimize the cascading of overland flows from one development to another, and therefore reduce the potential for property flooding.

3.4.4.1 Requirements

i. All trap lows must have a defined escape route. This escape route should be continuous through the development and any downstream areas. Escape routes should be shown on the applicable drawings and reports. See **Section 11.5.2** for required as-built information.

ii. **Standing water at trap lows should not exceed 0.5 m in depth. Where feasible, the maximum depth of ponding in trap lows shall be 0.3 m.** Ponding on arterial roads should be avoided where possible; approval for ponding is required by Wastewater & Drainage in these situations. Ponding on collector roads should be kept to a minimum where possible.

iii. Where possible, trap lows should be designed to contain all the flows generated from the 100 year event. Spillover is permitted on a limited basis as approved by Wastewater & Drainage.

iv. Required storage volumes must be determined through stormwater modelling. Trap low information should include depths, elevations and volumes for the 100 year requirement and the spill condition. See **Section 11.0 Technical Requirements** for further information.

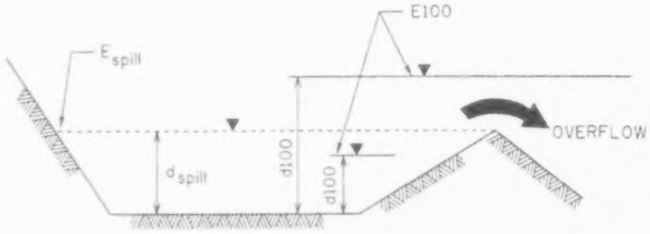


Figure 3.10: Trap Low Definition

v. Trap low depths and elevations will affect the minimum opening grade (MG and RMG) required for properties adjacent to the trap low. Restrictive covenants may also be required. See **Section 3.4.2 Lot Grading & Drainage**.

vi. The number of trap lows in lanes should be kept to a minimum due to space restrictions that may impact garage grades and driveways.

vii. Where possible, consideration should be given to locating trap lows away from arterial and collector roads, entrances to residential or local roads, and major intersections. These locations should be kept clear for emergency vehicle use.

viii. For Drainage & Site Servicing Plans, driveway entrances should be located away from trap lows located on public roads or property. It is the designer/consultant's responsibility to identify locations of trap lows in the adjacent public area.

3.4.4.2 Manhole Seals

Where possible, sanitary sewer manholes should be located outside of trap lows. For any sanitary sewer manholes located in trap lows, sanitary seals are required to reduce infiltration. Approved manhole sealing includes:

(a) Plastic or rubber plugs inserted into the holes of the manhole lid. One hole should be left open for access purposes, or
(b) One-hole manhole lid.

Manhole seals are also required on weeping tile manholes located in trap lows for designs that employ the three pipe system. The use of seals on storm manholes in trap lows is currently under investigation. **Parson inserts are not permitted.**

3.4.5 Roof Top Storage

Commercial, industrial and multi-family sites may use roof top storage as part of the on-site storage requirements. Refer to **Section 4.0 Drainage & Site Servicing Plans** for more information.

3.4.6 Swales

Grass and concrete swales are used to convey overland flows during minor and major rainfall events. In minor events, the swales are typically used to convey flows to catchbasins. In major events, higher velocities and depths of flow will be conveyed. Velocities and depths of flow should be carefully controlled. Q, v and d (flow, velocity and depth) should be indicated on the appropriate reports and drawings.

3.4.6.1 Grass

The use of grass swales must be carefully considered in terms of design.

i. Velocities and depths of flow for grass swales should not exceed the values outlined in **Section 3.4.3 Roads (v)**, Table 3.15 and Figure 3.9. Values outside of these limits must be approved by Wastewater & Drainage.

ii. Velocities in grass swales must be controlled so erosion does not occur. In general, the maximum permissible velocity for easily eroded soils should be maintained between 0.8 m/s and 1.8 m/s, depending on the vegetation cover and slope. For erosion resistant soils, the maximum permissible velocity should be maintained between 1.1 m/s and 2.4 m/s, depending on the vegetation cover and slope. This is based on information from "Handbook of Channel Design for Soil and Water Conservation". Alternate sources of information may be used for reference. Permissible velocities should be verified.

iii. Longitudinal slopes must ensure proper drainage and conveyance of flows. A minimum slope of 2% is recommended where possible. The use of grass swales in parks (MRs, ERs) also requires approval from Park Development & Operations.

iv. All flows, up to and including the 100 year flow, must be contained in the swale.

3.4.6.2 Concrete

Concrete swales, or gutters, are typically used to convey flow from back of lot drainage. **They are not intended to be used as overland escape routes.**

There are different types of concrete swales that are available. Please refer to City of Calgary "Standard Specifications Sewer Construction" for further information.

i. The minimum slope for concrete swales is 0.6%.

ii. **Standard** concrete swales are to be used when possible. Overland flows, up to and including the 100 year event, should be contained in the gutter. Use of the 1.2 m drainage easement to convey overland flows should be avoided; approval from Wastewater & Drainage is required. **Overtopping of the concrete swale is not permitted for lots that have back-to-front drainage.**

iii. **Deep** concrete swales are required when overland flows cannot be contained within a standard gutter.

iv. **Highback** concrete swales are required at points where the swale changes direction. Where possible, turns should be radiused to facilitate flow conveyance.

v. **Overland Escape Route** concrete swales are required at locations where the overland escape route is not along a roadway or paved pathway. This will typically include escape routes via Utility Right-of-Ways (where accepted), and may include PULs and MRs (at the discretion of Wastewater & Drainage). In general, the Overland Escape Route swale is 1 m wide (see Standard Specifications Sewer Construction). However, each situation must be evaluated separately to ensure the swale has adequate cross sectional area to convey the anticipated flows.

vi. Details showing the type of swale required and lengths must be shown on the construction drawings. City of Calgary specifications can be referenced as required.

vii. The number of lots draining to swales should be minimized. Swales were originally designed for grade control not flow conveyance.

viii. Fences crossing concrete swales should be kept a minimum of 4"-6" above the top of the swale to facilitate flows. **Blockage of the swale is not permitted.**

ix. Velocities and depths of flow for concrete swales should not exceed the values outlined in **Section 3.4.3 Roads (v)**, Table 3.15 and Figure 3.9. Values outside of these limits must be approved by Wastewater & Drainage.

3.4.7 Escape Routes

There must be **continuity** of overland flows between adjacent developments. A continuous overland escape route is required with conveyance of overland flows to appropriate safe points of escape or storage. Overland escape routes will always exist, whether one is planned or not. However, an unplanned escape route may lead to flooding or erosion. Therefore, it is important that an overland escape route be properly **planned, designed** and **controlled**. Overall overland escape routes should be planned at the Master Drainage Plan and Outline Plan levels. Specific details should be shown at the subdivision and DSSP (Drainage & Site Servicing Plan) levels.

Escape routes should always be via public roadways where possible. In no circumstance is an escape route to be through private property. When an escape route cannot be accommodated via roadway, PULs and MRs may be used (see Section 3.4.2 for lot grading requirements). Proper design of these areas as escape routes is required and is subject to approval by Wastewater & Drainage. Use of utility right-of-ways as overland escape routes is generally not acceptable; site-specific situations should be discussed with Wastewater & Drainage. The use of downhill cul-de-sacs is discouraged.

Concrete swales (gutters) and grass swales may only be used to convey overland flows from back of lot drainage. They are not intended to serve as overland escape routes. Fences or other obstacles must not impede overland flows; a drainage route free of obstacles is required. A clearance of 4"- 6" is recommended for fences, more if the flows are more significant.

Spillover elevations that determine escape routes must be carefully constructed, otherwise changes in the escape route may occur. Changes in the escape route can result in negative impacts to downstream areas and potential flooding. These spillover elevations must be included in the as-built information. See Section 11.5.2.

3.4.8 Receiving Waters

It is important to recognize that receiving waters form an integral part of both the major and minor drainage systems. Drainage does not end at the boundary of the development or site being designed. Stormwater management, along with erosion, flooding and water quality are the main concerns to be taken into consideration.

3.4.9 Outfall Channels

The use of open channels in Calgary has generally been minimal. When outfall channels are used, safety, aesthetics and maintenance costs must be considered. Approval from Wastewater & Drainage is required; approval from Park Development & Operations may also be required.

3.4.10 Stormwater Ponds

Stormwater ponds are the most commonly used forms for controlling runoff. They are an important component of the major system. In general, stormwater ponds consist of dry ponds, wet ponds, wetlands, and any hybrid ponds. Design criteria are outlined in **Section 6.0 Stormwater Ponds**.

3.5 Floodplain Requirements

Developments in floodplains and floodway areas are subject to the regulations described in **City of Calgary Bylaw 5P85**. Refer to Bylaw 5P85 for more information.

In general, all landowners or developers proposing construction within the 1:100 year floodplain of the Bow River, Elbow River and Nose Creek drainage basins are required to follow Bylaw 5P85. Floodplain maps are available at the Planning Policy/Building Regulations sales counter (Municipal Building).

i. No new buildings or other new structures shall be allowed except for the replacement of existing single family, semi-detached, duplex dwellings and accessory buildings on the same locations.

ii. No replacement of, external alterations or additions to existing buildings that might increase the obstruction to floodwaters on that site, or have a detrimental effect on the hydrological system or water quality, shall be allowed.

iii. Where development or redevelopment is permitted, the appropriate requirements will be made by the Special Projects Engineer in Wastewater & Drainage. The main requirements are as follows but is not limited to these:
    - The designated flood level is _____metres (Geodetic). The minimum first floor elevation shall be constructed at or above this elevation. All electrical and mechanical equipment shall be located at or above this elevation.
    - A sump pump should be provided in the basement with the outflow pipe looped and discharging above the designated flood level. Cut-off valves must be installed on the sewer lines or gravity flow basement drains must be eliminated.

3.6 Technical Requirements

Refer to **Section 11.0 Technical Requirements** for more information on required reports and construction drawings.

4.0 Drainage & Site Servicing Plans (Commercial/Industrial/Multi-Family)

4.1 General

In many respects, stormwater design of commercial, industrial, manufacturing, and multi-family lots is similar to or the same as stormwater design of subdivisions. Therefore, reference to other sections in this manual will be required. Overall, for minor system and major system component design, refer to **Section 3.0 Stormwater Design**. For sanitary design, please refer to City of Calgary's "Design Guidelines for Development Permits, Mechanical Site Plans and Solid Waste Services Plans".

It should be noted that Drainage & Site Servicing Plans (DSSP) were previously referred to as Mechanical Site Plans (MSP). All new documentation will refer to the new term, Drainage & Site Servicing Plans.

Drainage & Site Servicing Plans will generally be circulated through the Development Permit (DP) review process. See City of Calgary's "Design Guidelines for Development Permits, Mechanical Site Plans and Solid Waste Services Plans" for requirements and process review information. **All Drainage & Site Servicing Plans must be designed and prepared by qualified consultants; qualified consultants for drainage and sewer servicing typically include Civil or Municipal Engineering companies.**

4.2 Minor System

The **minor** system provides a basic level of service by conveying flows from the more common (low intensity, more frequent) rainstorm events. The system consists of the underground network of pipes and associated structures. Components of the minor system typically include: gutters and roof leaders, weeping tile, lot drainage, catchbasins, inlets and leads, underground pipe system, manholes and junctions, outfalls, and receiving waters. Some components may be classified under both minor and major system components.

4.2.1 General Requirements

i. The storm sewer pipe (minor) system must be designed as a **separate system** from the sanitary. Combined systems are not permitted.

ii. In general, the storm sewer must be designed to convey design flows when flowing full with the hydraulic grade line (HGL) at or below the crown of the pipe. Sewer Pipes should not surcharge for design or 100 year flows unless previously approved by Wastewater & Drainage. **Surcharge to ground surface is strictly prohibited.**

iii. The minor system is to be designed according to the level of service stipulated in **Section 4.2.2**. The majority of sites will be designed using the Unit Area Release Rate Method.

4.2.2 Level of Service

A basic level of service is provided by the minor system. In Calgary, this has typically been sized for the 5 year return period storm since 1952. Prior to 1952, the level of service was based on a 2 year return period storm. In Calgary, sizing of the storm trunks was previously done using the **Rational Method** design.

The City of Calgary has adopted a new approach to storm trunk design. This is known as the **Unit Area Release Rate Method**. This method uniformly distributes the storm trunk capacity, on a per hectare basis, for the area tributary to the storm trunk. Refer to "Stormwater Management Methodology" by Reid Crowther & Partners Ltd. (1992) for more information.

For all new areas, the minor system must be designed using the Unit Area Release Rate Method (L/s/ha). In general, the recommended minimum release rate is 70 L/s/ha. In steeper terrain, where on-street storage is minimal, the design rate must be higher. **Permitted lot release rates will be specified in the subdivision construction drawings when servicing is available. These release rates must be strictly adhered to.**

4.2.2.1 Unit Area Release Rate Method

For all new areas, the minor system must be designed using the Unit Area Release Rate Method (L/s/ha).

Refer to **Section 3.1.2.3 Unit Area Release Rate Method**.

Figure 4.1 should be used instead of Figure 3.1 for determining storage requirements for DSSP lots. See **Section 4.7.1.2**.

4.2.2.2 Modified Unit Area Release Rate Method

Until such time as all drainage catchments are designed using the Unit Area Release Rate Method, a modified method may have to be used for design of the minor system. The modified method should only be used when there is sufficient drainage area remaining in a catchment (> 30 ha), there are no stormwater ponds, and where the storm trunk was originally designed using the Rational Method.

Refer to **Section 3.1.2.4 Modified Unit Area Release Rate Method**.

4.2.2.3 Rational Method

The Rational Method can only be used for the design of the minor system for **remaining catchment areas** that were originally designed using this method, provided the remaining area is ≤ 30 ha. Areas larger than 30 ha should be designed using the Unit Area Release Rate Method or the Modified Unit Area Release Rate Method. Use of the Rational Method should be limited where possible. For sites ≤ 2 ha, the methodology outlined in **Appendix B** can be utilized; also refer to **Section 4.7.1.1**.

Refer to **Section 3.1.2.5 Rational Method**.

Runoff Coefficients C

For industrial, commercial and multi-family lots, the following runoff coefficients (C) should be used:

1.0	Roof
0.9	Pavement
0.5	Gravel
0.3	Landscaping

NOTE: Runoff Coefficients are subject to approval by Wastewater & Drainage

4.3 Major System

The **major** stormwater drainage system conveys runoff from extreme rainfall events that are in excess of the minor underground system. Components of the major system typically include: gutters and roof leaders, lot drainage, roads, swales, trap lows, escape routes, storage facilities (ponds), culverts, outfalls, and receiving waters. Some components may be classified under both minor and major system components.

A major system will always exist, whether or not one is planned. Failure to properly plan a major system will often result in unnecessary flooding and damage. Therefore, it is important to examine grading plans to ensure there is an overland route that has reasonable capacity.

4.3.1 General

i. The major system must be designed as an overland system.

ii. A continuous escape route must be provided for the overland flows. Adjacent properties must be protected from flooding by these flows.

iii. The major system is to be sized according to the level of service stipulated in **Section 4.3.2**.

4.3.2 Level of Service

In Calgary, the major system must be designed for the 100 year return period storm. This includes all stormwater and evaporation ponds. This is to provide a reasonable level of flood protection. Drainage & Site Servicing Plans must provide on-site retention to contain the 100 year design.

4.4 Minor System Component Design

This section outlines the design criteria that apply to the components of the minor system for Drainage & Site Servicing Plans. Refer to **Section 3.3 Minor System Component Design** for information on the following components:

Section 3.3.2	Pipes
Section 3.3.3	Manholes
Section 3.3.4	Catchbasins
Section 3.3.5	Inlet Control Devices
Section 3.3.6	Weeping Tile (Foundation Drain)
Section 3.3.7	Outfalls
Section 3.3.8	Culverts
Section 3.3.9	Pumping

4.4.1 Service Connections

Service connections are required to provide storm sewer service. These connections are considered to be private and all expenses are at the developer/owner's expense. Appropriate approval for connection is required by Wastewater & Drainage.

4.4.1.1 General

i. No portion of private sewer systems are permitted in bylawed setback areas except for service connections.

ii. Extensive and/or complicated external sewer systems shall be installed with the surveyor's grade sheets and batter boards. Where this is required, Drainage & Site Servicing Plans will be stamped for inspection purposes.

iii. Comments regarding development permit requirements are provided to the applicant prior to circulation of the Drainage & Site Servicing Plan. It is the designer/consultant's responsibility to ensure the drawings meet current stormwater design standards. Adjacent site conditions (ie. trap lows, berms, etc.) should be identified and taken into account to ensure adequate site design.

4.4.1.2 Servicing

i. Servicing connections are to be made to the public storm sewer.

ii. An existing service connection may be used if it has adequate capacity and is inspected and approved by Wastewater & Drainage, Manchester Office (268-4910).

iii. Separate services are required for different properties whether or not the property or lot lines are existing or proposed.

iv. Force mains and private sewers are not permitted on City property.

v. Designers/consultants must ensure that sump pumps are adequately sized.

4.4.1.3 Location

i. Service connection locations must be made at right angles to the City sewer main.

ii. Connection lines must be located relative to property lines.

iii. Sanitary sewer manholes and cleanouts will not be permitted within stormwater retention areas (trap lows, ponds, etc.)

4.4.1.4 Grades

Existing and proposed invert elevations, and the invert of the service lead at the property line will be checked by the Building Grade Supervisor and indicated on the plan. Use the invert elevations given by the Building Grade Supervisor and revise design as necessary at re-submission. In special cases, especially downtown areas, the sewer connection must be pre-installed to the site prior to on-site sewers being installed due to possible conflicts with other utilities in the street.

For **private subdivisions**, grades at the property line should be set by accounting for the following:

- Adding slope of pipe
- Allowing for construction and datum error
- Allowing more grade if there is a possible conflict with other utilities
- Hydraulic grade line (HGL) elevations where surcharge conditions occur

4.4.1.5 Manholes

A manhole is required on a main for a connection when:

i. The diameter of the connection line is greater than one half the diameter of the main.

ii. The length of the service connection from the building to the main is greater than 30 m.

Otherwise, direct connection to the main sewer is permitted. Refer to City of Calgary "Standard Specifications Sewer Construction" for details. Where possible, a cover of 1.2 m over the storm pipe should be maintained for frost protection.

4.5 Major System Component Design

This section outlines the design criteria that apply to the components of the major system for Drainage & Site Servicing Plans. Refer to **Section 3.4 Major System Component Design** for information on the following components:

Section 3.4.1	Roof Leaders
Section 3.4.2	Lot Grading & Drainage
Section 3.4.3	Roads
Sections 3.4.4/4.7.1	Trap Lows (Surface Ponding)
Section 4.7.2	Roof Top Storage
Section 3.4.6	Swales
Section 3.4.7	Escape Routes
Section 3.4.8	Receiving Waters
Section 3.4.9	Outfall Channels
Sections 6.0	Stormwater Ponds
Sections 4.6/4.8	Evaporation Ponds

4.6 Servicing

4.6.1 Serviced Sites

Storm connection is required in areas where storm servicing is available. Connection locations are indicated in the standard development permit comments. Permitted release rates (L/s/ha) will also be identified where possible. However, it is the designer/consultant's responsibility to determine permitted flow rates based on the approved construction drawings. Areas where the hydraulic grade line (HGL) is a concern are also indicated on the approved construction drawings.

It is important that the permitted design flow for the lot is not exceeded. To ensure the design flow to the public main is not exceeded, two methods are available. In order of preference, these methods are:

1) **Reduced Pipe Size:** The last pipe section that ties into the public main can be reduced to the appropriate size (based on any head conditions that exist). However, pipe sections smaller than 150 mm diameter should consider an alternate type of restriction.

2) **Bolted ICD Plates:** **Bolted** ICD plates will be considered for the last pipe segment that ties into the public main. The ICD must be installed in a manhole on the outgoing pipe. The ICD must be bolted in place. **The owner is responsible for any downstream flood damage that may occur from removal of the bolted ICD.**

4.6.2 Non-Serviced Sites

In general, development is **not** permitted unless servicing is available. However, Wastewater & Drainage will permit development in some areas provided certain conditions are met. Contact Wastewater & Drainage for more information.

For lots in Section 23-23-29-4, Moratorium comments are applicable. Contact Wastewater & Drainage for information. In this area, approved DPs (Development Permits) are temporary for a one year period. Terms of approval may change from year to year with the development of a public storm sewer.

Dry Wells

When storm sewers are not available, a temporary dry well system may be considered. Approval is at the discretion of Wastewater & Drainage. Dry wells will only be considered for small lots (< 1 ha) where soil conditions allow for adequate drainage; dry wells located near slopes require geotechnical consideration. Dry wells are only permitted until such time as servicing becomes available. Refer to City of Calgary "Standard Specifications Sewer Construction", file number 452.1002.019 for details. Otherwise, see **Section 4.8** for more information.

Parking Lots

In the downtown core (Bow River to 9th Ave. S. and Elbow River to 14 St. W.), dry wells will be permitted for gravel parking lots or gravel parking lots with paved lanes for a period not exceeding 5 years. It the lot is to be in service longer, a storm connection is required. Paved lots in the downtown core and all parking lots (paved or gravel) outside of the downtown core must have a storm connection.

Evaporation Ponds

In some areas where servicing is not available, evaporation ponds may also be considered at the discretion of Wastewater & Drainage. Evaporation ponds will be considered where the lot is large and the proposed imperviousness will remain low. See **Section 4.8** for more information.

4.7 Storage Requirements & Methods

The major system must be designed for the 100 year return period storm. This is to provide a reasonable level of flood protection. Drainage & Site Servicing Plans must provide on-site retention to contain the 100 year design. Retention can be accomplished by means of roof top storage, trap low storage, underground storage or stormwater ponds. See **Section 4.8** for more information.

4.7.1 Manual Calculations/Graphs

For small sites $\leq$ 2 ha, required 100 year storage volumes can be tabulated through manual calculations or graphs as provided in the following sections.

4.7.1.1 Rational Method

For sites where servicing is available and the Rational Method is permitted, the method outlined in **Appendix B** may be used to determine the required 100 year storage volume.

4.7.1.2 Unit Area Release Rate Method

For sites where servicing is available and the permitted release (or design discharge) is specified in L/s/ha, Figure 4.1 may be used to determine the required 100 year storage volume.

Steps

1) Based on the release rate and overall site imperviousness, determine the required maximum storage volume (m^3/ha) from the Figure 4.1. Values may be interpolated if required.

2) Determine required 100 year volume.

$$V100 = \text{Required Storage } (m^3/ha) \times A$$

where: V100 = volume required for 1:100 year event (m^3)
A = total area of site (ha)

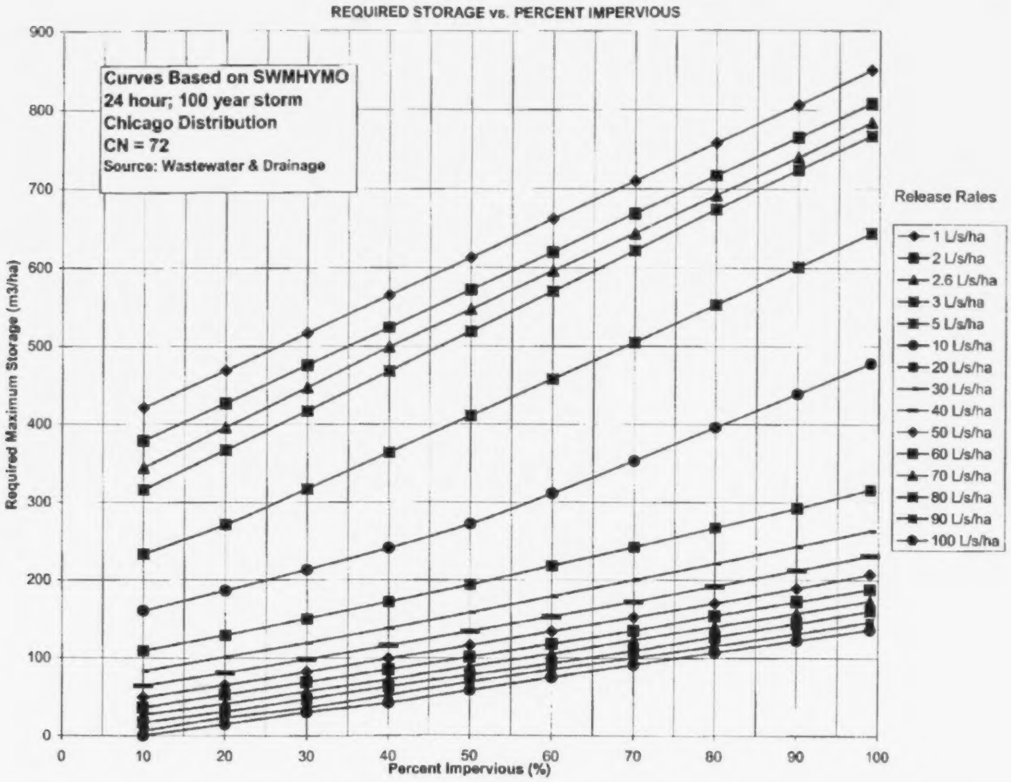


Figure 4.1: Required Storage vs Imperviousness for Unit Area Release Rate Method

4.7.2 Computer Modelling

Computer modelling is required to determine the 100 year storage volume requirements for the following situations:

i. Serviced sites larger than 2 ha
ii. Sites that require stormwater ponds
iii. Non-serviced sites larger than 2 ha

For computer modelling requirements, see **Section 3.0 Stormwater Design** for more information.

4.8 Storage Options

Storage may be accomplished through several methods which include parking lot storage (trap lows), roof top storage, underground storage, stormwater ponds and evaporation ponds. Servicing of the site and the permitted discharge or release rate will determine which methods of storage are viable.

4.8.1 Parking Lot Storage (trap lows)

Parking lot storage in the form of trap lows is typically the most common form of volume storage. Provided grades on the lot are not steep, **and** the permitted release rate is reasonably high (≈ 50 L/s/ha or higher), no additional storage may be required. For design of trap lows, refer to **Section 3.4.4 Trap Lows (Surface Ponding)**.

4.8.2 Roof Top Storage

Where roof top storage is provided, the following information should be provided on the drawings or plans:

- Roof boundary and any drainage boundaries where the roof encompasses a large area.
- Roof top storage volume(s)
- Location of roof drain(s)
- Number of roof drains
- Flow per roof drain
- Total flow from drain

4.8.3 Dry Wells

A temporary dry well system may be considered for lots where storm sewers are not available. Approval is at the discretion of Wastewater & Drainage. Dry wells will only be considered for small lots (< 1 ha) where soil conditions allow for adequate drainage; dry wells located near slopes require geotechnical consideration. Gravel based soils typically allow for sufficient drainage.

Refer to City of Calgary "Standard Specifications Sewer Construction", file number 452.1002.019 for details. The minimum number of dry wells must be determined by the flow generated from the site in relation to the intake capacity of the soil in the dry well structure. Sufficient temporary storage (ie. trap lows) surrounding the dry well must be constructed to contain generated flows until such time as they infiltrate into the subsurface. The use of dry wells is not generally recommended where other storage options provide better protection and servicing.

4.8.4 Underground

When surface storage is not sufficient to provide all of the storage requirements, alternative storage methods such as underground storage will be considered. All underground storage designs are at the discretion and approval of Wastewater & Drainage. Infiltration and/or percolation into the subsoil are not permitted.

4.8.5 Stormwater Ponds

Stormwater ponds may be required for the following:

- Large sites
- Sites where imperviousness is high
- Sites where the permitted release rate is low
- Sites requiring water quality
- Non-serviced sites

When stormwater ponds are required, design should conform to the requirements listed in the following sections:

Section 6.1	General
Section 6.2	Dry Ponds
Section 6.3	Wet Ponds
Section 6.4	Wetlands

Since the stormwater ponds will be on private sites, monitoring equipment will not be required. Water quality monitoring for wet ponds and wetlands is at the discretion of Wastewater & Drainage; normally water quality monitoring will not be required unless under special circumstances. Wastewater & Drainage may also request fencing of the pond area if safety is an issue. All required pond details and design requirements must be included on the DSSP plans or drawings.

Non-serviced sites requiring evaporation ponds must conform to the general requirements for stormwater ponds, depending on the type of stormwater pond required (typically wet pond or wetland). See Section 6.0 Stormwater Ponds for design requirements. Refer to **Section 4.8.6 Evaporation Ponds** for storage volume requirements.

4.8.6 Evaporation Ponds

In some areas where servicing is not available, evaporation ponds may be considered at the discretion of Wastewater & Drainage. Evaporation ponds will be considered where the lot is sufficiently large enough to contain an evaporation pond and the proposed imperviousness will remain low. Evaporation ponds will typically occupy 30% to 50% of the total site area.

Evaporation ponds must conform to the general requirements for wet ponds or wetlands, whichever is required. Refer to **Section 6.0 Stormwater Ponds** for further design information.

Sites ≤ 2 ha

For sites ≤ 2 ha, the required 100 year volume per ha can be obtained from Figure 4.2. Use of this figure requires determination of the overall site imperviousness and the percentage of the overall area that the evaporation pond will cover. Volume requirements are based on evaporation only; an allowance for potential irrigation is **not** permitted. To determine the required 100 year volume:

V100 = Storage Required (m3/ha) x Site Area (ha)

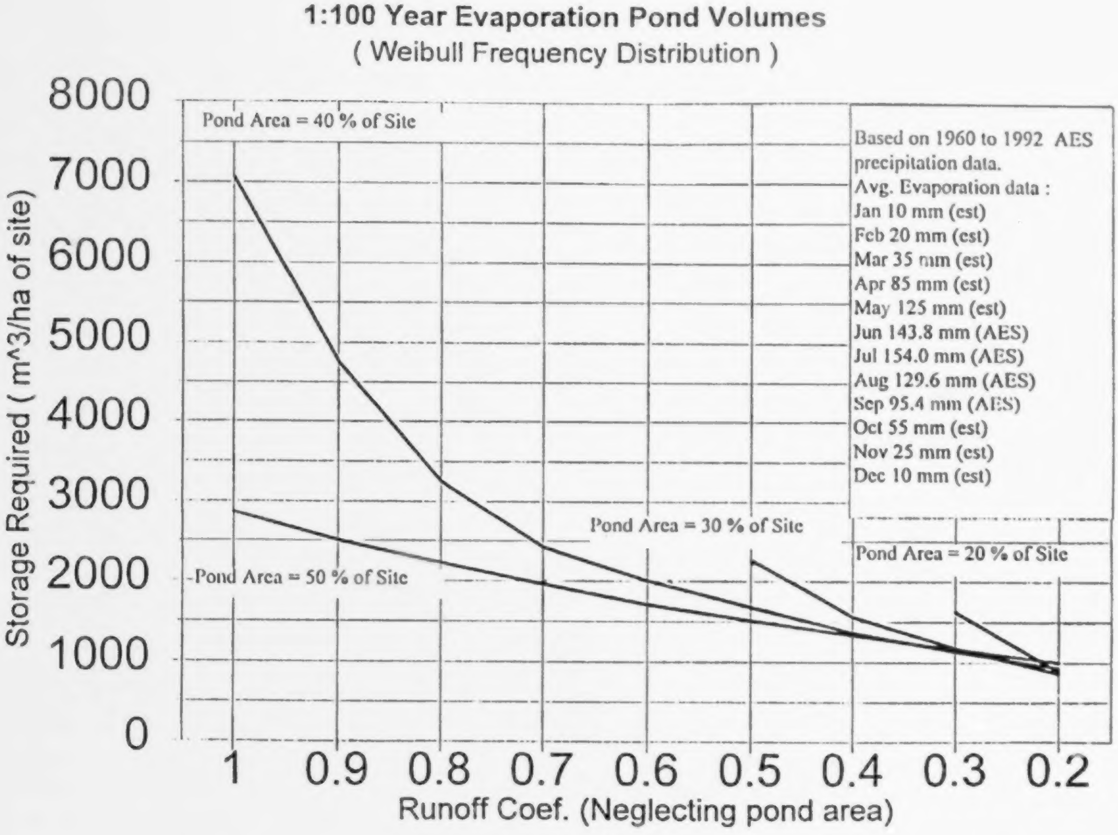


Figure 4.2: **100 Year Evaporation Pond Volumes for DSSPs**

Sites > 2 ha

For sites > 2 ha, the required 100 year volume must be determined through computer modelling. A continuous model (QUALHYMO, QHM or SWMM) must be used.

Steps

1) Use a continuous simulation model such as QUALHYMO, QHM or SWMM as approved by Wastewater & Drainage.
2) The model should be set up such that no outflow is permitted from the site. **Only evaporation is permitted; irrigation or other potential methods of reducing volumes is not permitted.**
3) The computer model will generate maximum yearly volumes. A statistical analysis must then be done using these yearly volumes to determine the required 100 year storage volume. Simply using the maximum storage volume generated over the time period is **not** correct. Different distributions can be used in the regression analysis: Gumbel, Weibull, Normal, Log Normal, Pearson, Log-Pearson, etc. When choosing the best distribution for storage volume, the distribution with the best fit should be chosen. Best fit should be considered in terms of correlation and standard error.
4) Evaporation, rainfall and temperature information for the computer model is available from Meteorological Service of Canada (MSC). The designer/consultant is responsible for obtaining the required input data and use of the appropriate model.

4.8.7 Pond Approvals

All stormwater ponds (ie. dry ponds, wet ponds, and wetlands) require the appropriate approvals from Wastewater & Drainage and Alberta Environment prior to construction. Pursuant to the Environmental Protection and Enhancement Act (EPEA), approval is required for the construction of all stormwater ponds. The consultant is responsible for preparing and submitting the information to Wastewater & Drainage. Wastewater & Drainage will apply for approval to Alberta Environment. A 30 day public notification period is required. Refer to **Appendix A** for required information. For more information, see **Section 2.0 Approvals & Processes**.

For non-serviced sites requiring evaporation ponds, contact Wastewater & Drainage for the current approval policy.

4.9 Hydraulics

In general, hydraulic design of the storm pipe system for a DSSP lot is not complicated for small sites. However, where large sites (> 2 ha) are involved, additional care must be taken in the design of the storm pipe system. **Section 5.0 Hydraulic Design** should be consulted for more information. Further information regarding hydraulic requirements for pipes and weeping tile can be found in **Sections 3.3.2.10** and **3.3.6.6**. It is the designer's responsibility to ensure that on-site storm pipe system functions properly. Hydraulic conditions from the adjacent public main or stormwater ponds must also be taken into consideration where required.

4.10 Lot Grading & Drainage

Carefully designed and controlled lot grading is an important component of the Major System and good stormwater management. Without proper grading, buildings and adjacent properties may be subject to flooding. All grading details such as berm elevations and cross sections, escape route elevations and cross sections, pond grading information, trap low grading, and top of slab elevations should be carefully planned and shown on the applicable drawings or plans.

Refer to **Section 3.4.2** for lot grading and drainage information. For all other drainage components, refer to **Section 3.4 Major System Component Design**.

4.11 Water Quality

In the past there has been a tendency to regard stormwater as a relatively minor source of pollution. However, numerous studies have found that there can be significant pollution in stormwater runoff. Contaminants from commercial and industrial lots can be a significant source of pollution if measures are not taken to mitigate the problem. The implementation of Best Management Practices (BMPs) can help mitigate these pollution problems and enhance urban runoff quality (see **Section 8.0 Best Management Practices**).

The City of Calgary must meet regulatory requirements for water quality of urban runoff. The current objective is to provide a minimum of 80% removal of total suspended solids (TSS) for particle sizes ≥75μm. All wet ponds and wetlands are required to provide enhanced water quality. **Site specific areas may also be required to provide water quality enhancement. This may include, but is not limited to, industrial and commercial sites.**

Refer to **Section 7.0 Water Quality** for further information on requirements and water quality modelling.

4.12 Best Management Practices

Best Management Practices, or BMPs, are activities or practices, or a combination of practices, that are designed to prevent or reduce the release of pollutants to receiving waters or streams. BMPs operate by trapping stormwater runoff and detaining it until unwanted pollutants such as sediment, phosphorous and other harmful contaminants are allowed to settle out or be filtered through underlying soils. The trapped pollutants are then removed through periodic maintenance.

The selection and design of stormwater BMPs must incorporate both water quantity and water quality concerns. Current stormwater quality criteria for the City of Calgary requires the removal of a minimum of 80% total suspended solids (TSS) for particle sizes ≥75μm. By 2003, pollutant loading criteria will be established that will identify additional pollutant controls. Although not all BMPs may be able to meet this criteria, they do go a long way in reducing pollutant runoff. Care should be made in selecting the appropriate BMP or combination of BMPs.

Use of BMPs is recommended for **all** sites. However, BMPs are **required** for the following sites:

- large sites (> 2 ha)
- gas stations
- heavy industrial and manufacturing sites

Installation and maintenance costs of all on-site BMPs are to be borne by the owner.

Although there are several BMPs that can be implemented, the BMPs recommended by Wastewater & Drainage for DSSPs are oil/grit separators, filter strips, grassed swales, and stormwater ponds (where required). It is the designer/consultant's responsibility to ensure that all BMPs are properly designed according to site conditions or constraints, and that details are provided on the drawings. **All BMPs require the approval of Wastewater & Drainage.**

Refer to **Section 8.0 Best Management Practices** for more information and details.

4.13 Erosion & Sediment Control

Urbanization can have a profound impact on the quality of Calgary's rivers, streams and creeks. Construction activities can result in a rapid increase in erosion and sedimentation, and if left uncontrolled, can irreparably harm the environment, resulting in loss of valuable topsoil, and the subsequent sedimentation of rivers and other water bodies. Sedimentation of our rivers, streams and creeks can negatively affect water supplies, flood control, fish habitat and fishing, navigation, and recreational activities. On average, erosion rates for construction sites with no erosion control measures are 200-400 times higher than natural erosion rates for rural land use. However, erosion and sediment control techniques can help protect these valuable resources by reducing the environmental impacts caused by sediment entering our receiving streams.

Refer to **Section 9.0 Erosion & Sediment Control** for more information and details. The City of Calgary "Guidelines for Erosion & Sediment Control" should also be referenced. **Section 8.2** provides additional information on Source Control BMPs for good housekeeping practices.

Requirements

There is federal, provincial and municipal legislation governing either urban development or sediment control in general. This is discussed in more detail in **Section 2.0 Approvals and Processes** and **Section 9.1.4**. Failure to comply with the legislation can result in a fine and/or imprisonment.

All sites ≤ 2 ha require the use of good housekeeping practices (see Sections 8.2, 9.4.1 and 9.7) and where practicable, erosion and sediment controls to control runoff on-site. Sites larger than 2 ha require erosion and sediment controls in keeping with the size of the site, the construction activities, and the length of time for construction. In general, all runoff should be controlled on-site. Typical measures may include but are not limited to perimeter silt fencing, barriers, and impoundments. Erosion & Sediment Control details must be provided on the drawings.

4.14 Technical Requirements

Refer to **Section 11.0 Technical Requirements** for more information on required reports and drawings.

5.0 Hydraulic Design

5.1 Need for Hydraulic Considerations

Hydraulic design of a storm sewer system requires the understanding of basic hydrology and hydraulic concepts and principles. The hydraulic design of a storm sewer system should take into account the effects of backwater, surcharging, inlet capacity and energy losses in the system. The complexity of the system will determine the extent that these factors must be considered. A hydraulic analysis may be required to ensure that the pipe system operates properly, otherwise excessive surcharging and flooding can occur. Important hydraulic principles include flow classification, conservation of mass, conservation of momentum, and conservation of energy.

When the pipe system is flowing partially full, the system acts as an open channel, where there is a free water surface. However, when the pipe is flowing full, the system starts acting as a pressure (or pipe) flow system. It is important that pipes and appurtenances be properly designed to minimize and/or alleviate surcharging of the pipe system.

5.2 General

There is a loss of energy when flow passes through a bend in the sewer, a manhole, junctions, or transitions. The losses can be small or substantial depending on the system design. The energy losses from large diameter pipes flowing full and turning 90^0 can be very large. It is the designer's responsibility to provide a system that is hydraulically smooth.

Flow Type

Various categories of flow can be identified: steady, unsteady, uniform, non-uniform (varied), gradually varied, and rapidly varied. Channel flow is distinguished from closed conduit (pipe) flow based on the fact that the cross section of flow is not solely dependent on the geometry of the conduit, but also on the free surface (or depth). The free surface will vary with respect to space and time and is a function of the discharge.

For the design of storm systems, an assumption is made that the flow is steady and uniform. This means that the flow and depth in each reach is assumed to be constant with respect to time. However, in reality the flow at each inlet may be variable and flow conditions are not totally steady or uniform.

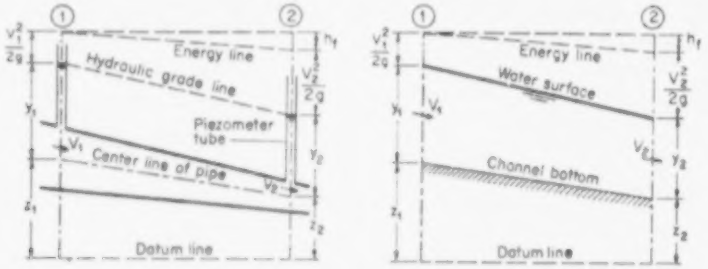
Two design philosophies exist for sizing storm systems under steady uniform flow conditions: open channel (or gravity flow) and pressure flow. The flow in a closed conduit is not necessarily pressure flow; if the flow has a free surface, it is classified as open channel (ie. pipes flowing less than full). When pipes start flowing under pressure, design for pressure flow must be considered.

Bernoulli Equation

The law of conservation of energy expressed by the Bernoulli Equation is the basic principle most often used in hydraulics. The equation may be applied to any conduit with a constant discharge. The law states that the energy head at any cross-section must equal that in any other downstream section plus the intervening losses. The Bernoulli equation may be used in both open channel and closed conduit (pressure) flow.

Hydraulic and Energy Grade Lines

Hydraulic and energy grade lines are useful in hydraulic analysis. See Figure 5.1 (Ven te Chow, 1959). The hydraulic grade line (HGL) is a measure of flow energy and is represented by the level of water maintained by the pressure exerted by the fluid in the pipe. The energy grade line (EGL) is the total energy in the flow, taking into account the velocity head ($v^2/2g$). Loss of energy due to fluid flowing from section to section is defined as h_f.


①
②
$\frac{V_1^2}{2g}$
h_f
Energy line
Hydraulic grade line
$\frac{V_2^2}{2g}$
y_1
Piezometer tube
V_1
Center line of pipe
V_2
y_2
z_1
z_2
Datum line
①
②
$\frac{V_1^2}{2g}$
Energy line
h_f
Water surface
$\frac{V_2^2}{2g}$
y_1
V_1
V_2
y_2
Channel bottom
z_1
z_2
Datum line

Pipe flow

Open-channel flow

Figure 5.1: Energy in Closed Conduit (pipe) and Open Channel

5.3 Energy Losses

The hydraulic capacity of a storm system is controlled by its size, shape, slope and friction resistance. When using the Bernoulli Equation for hydraulic design, it is necessary to account for the energy losses. The losses are expressed in terms of head and may be classified as:

(a) **Friction Losses**- Losses due to the shear stress between the moving fluid and the boundary material.

(b) **Form Losses**- Losses caused by abrupt transitions resulting from the geometry of manholes, bends, expansions, and contractions.

It is a common mistake to include only friction losses in the hydraulic analysis when form losses can constitute a major portion of the total head loss. It is important to take form losses into account in the design of the system.

The following information is provided as a guideline. The designer or consultant is responsible for consulting appropriate references and ensuring proper design. All pipe systems must be hydraulically designed. The following references are included but should not be limited when other sources may be available:

- **(a) ASCE Manual and Report No. 77/WEF Manual of Practice FD-20, "Design and Construction of Urban Stormwater Management Systems"**
- **(b) Corrugated Steel Pipe Institute, "Modern Sewer Design"**
- **(c) Ven Te Chow, "Open Channel Hydraulics"**
- **(d) American Public Works Association, "Urban Stormwater Management-Special Report 49"**
- **(e) J. Marsalek, "Head Losses at Selected Sewer Manholes", NWRI 85-15**
- **(f) U.S. Department of Transportation, "Urban Drainage Design Manual-Hydraulic Engineering Circular No. 22", FWHA-SA-96-078**

5.3.1 Pipe Friction Losses

The major loss in a channel or pipe system is the friction or boundary shear loss. The head loss is computed from the general definition:

$$H_f = S_f L \qquad \textbf{Equation 5.1}$$

where:
H_f = head loss due to friction
S_f = average friction slope
L = length of channel or pipe

Depending on flow conditions, the friction slope (S_f) can be computed from one of several friction formulas:

1) **Hazen-Williams Formula**- smooth flow in a pipe
2) **Darcy-Weisbach Equation**- primarily for flow in pipes
3) **Manning Equation**- uniform and gradually varied flow in pipes and open channels.

5.3.2 Form Losses

Aside from friction losses, energy losses also include form losses, also known as minor losses. These losses are caused by sudden changes due to transitions, bends, junctions, entrances, exits, obstructions, and control devices (ie. orifices and gates). If the pipe is long (L/D>>1000), form losses are usually very small in comparison to the friction losses, and can be neglected. However, if the pipe is very short and/or there are a number of manholes, changes in direction, junctions, or changes in pipe size, then these losses can exceed the friction losses.

Form losses are expressed either as a coefficient times the velocity head, or as a coefficient times the difference in velocity heads, depending on the type of loss. In general, minor losses are expressed as:

$$H_L = K_c\,(v^2/2g) \qquad \textbf{Equation 5.2}$$

where: H_L = minor head loss
K_c = loss coefficient
$v^2/2g$ = velocity head

There are several types of losses that should be taken into account.

Transition Losses (K_e, K_c)

A transition occurs where a pipe or channel changes size. The change in cross-sectional area results in a change in velocity, and therefore a loss of head. The energy losses are defined for expansion and contraction.

Expansion:

$$H_e = K_e\,(v_1-v_2)^2/2g \quad \text{for } v_1>v_2 \qquad \textbf{Equation 5.3}$$

Contraction:

$$H_c = K_c\,(v_2-v_1)^2/2g \quad \text{for } v_2>v_1 \qquad \textbf{Equation 5.4}$$

where: H_e, H_c = head loss due to expansion or contraction
K_e, K_c = transition loss coefficients
v_1 = upstream velocity above the transition
v_2 = downstream velocity below the transition

These expansion and contraction losses are for non-pressure flow. See Figure 5.2 for typical transition loss coefficients.

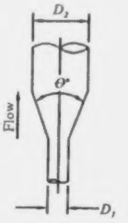
Figure 5.2: Typical K_e and K_c Values for Non-Pressure Flow

(Linsley and Franzini 1964)

(a) Expansion (K_e)

θ*	$\frac{D_2}{D_1} = 3$	$\frac{D_2}{D_1} = 1.5$
10	0.17	0.17
20	0.40	0.40
45	0.86	1.06
60	1.02	1.21
90	1.06	1.14
120	1.04	1.07
180	1.00	1.00

*The angle θ is the angle in degrees between the sides of the tapering section.

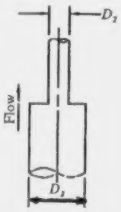


(b) Pipe Entrance from Reservoir

Bell-mouth	$H_L = 0.04 \frac{V2}{2g}$
Square-edge	$H_L = 0.5 \frac{V2}{2g}$
Groove end U/S For Concrete Pipe	$H_L = 0.2 \frac{V2}{2g}$

(c) Contractions (K_c)

$\frac{D_2}{D_1}$	K_c
0	0.5
0.4	0.4
0.6	0.3
0.8	0.1
1.0	0



For pipes under pressure flow, expansion and contraction head losses are defined as follows:

$$H_e = K_e (v_1)^2/2g \quad \text{and} \quad H_c = K_c (v_2)^2/2g \qquad \text{Equation 5.5}$$

Under pressure flow conditions, Tables 5.1, 5.2 and 5.3 (AISI 1996) should be used for determining transition loss coefficients.

Table 5.1: Values of K_e for Sudden Enlargement in Pipes (AISI 1996)

d_2/d_1 = ratio of larger pipe to smaller pipe V_1 = velocity in smaller pipe

$\frac{d_2}{d_1}$	Velocity, V_1, in metres per second												
	0.6	0.9	1.2	1.5	1.8	2.1	2.4	3.0	3.6	4.5	6.0	9.0	12.0
1.2	.11	.10	.10	.10	.10	.10	.10	.09	.09	.09	.09	.09	.08
1.4	.26	.26	.25	.24	.24	.24	.24	.23	.23	.22	.22	.21	.20
1.6	.40	.39	.38	.37	.37	.36	.36	.35	.35	.34	.33	.32	.32
1.8	.51	.49	.48	.47	.47	.46	.46	.45	.44	.43	.42	.41	.40
2.0	.60	.58	.56	.55	.55	.54	.53	.52	.52	.51	.50	.48	.47
2.5	.74	.72	.70	.69	.68	.67	.66	.65	.64	.63	.62	.60	.58
3.0	.83	.80	.78	.77	.76	.75	.74	.73	.72	.70	.69	.67	.65
4.0	.92	.89	.87	.85	.84	.83	.82	.80	.79	.78	.76	.74	.72
5.0	.96	.93	.91	.89	.88	.87	.86	.84	.83	.82	.80	.77	.75
10.0	1.00	.99	.96	.95	.93	.92	.91	.89	.88	.86	.84	.82	.80
∞	1.00	1.00	.98	.96	.95	.94	.93	.91	.90	.88	.86	.83	.81

Table 5.2: Values of K_e for Gradual Enlargement in Pipes (AISI 1996)

d_2/d_1 = ratio of diameter of larger pipe to diameter of smaller pipe. Angle of cone is twice the angle between the axis of the cone and its side.

$\frac{d_2}{d_1}$	Angle of cone													
	2°	4°	6°	8°	10°	15°	20°	25°	30°	35°	40°	45°	50°	60°
1.1	.01	.01	.01	.02	.03	.05	.10	.13	.16	.18	.19	.20	.21	.23
1.2	.02	.02	.02	.03	.04	.09	.16	.21	.25	.29	.31	.33	.35	.37
1.4	.02	.03	.03	.04	.06	.12	.23	.30	.36	.41	.44	.47	.50	.53
1.6	.03	.03	.04	.05	.07	.14	.26	.35	.42	.47	.51	.54	.57	.61
1.8	.03	.04	.04	.05	.07	.15	.28	.37	.44	.50	.54	.58	.61	.65
2.0	.03	.04	.04	.05	.07	.16	.29	.38	.46	.52	.56	.60	.63	.68
2.5	.03	.04	.04	.05	.08	.16	.30	.39	.48	.54	.58	.62	.65	.70
3.0	.03	.04	.04	.05	.08	.16	.31	.40	.48	.55	.59	.63	.66	.71
∞	.03	.04	.05	.06	.08	.16	.31	.40	.49	.56	.60	.64	.67	.72

Table 5.3: Values of K_c for Sudden Contraction (AISI 1996)

d_2/d_1 = ratio of larger to smaller diameter V_2 = velocity in smaller pipe

$\frac{d_2}{d_1}$	Velocity, V_2, in metres per second												
	0.6	0.9	1.2	1.5	1.8	2.1	2.4	3.0	3.6	4.5	6.0	9.0	12.0
1.1	.03	.04	.04	.04	.04	.04	.04	.04	.04	.04	.05	.05	.06
1.2	.07	.07	.07	.07	.07	.07	.07	.08	.08	.08	.09	.10	.11
1.4	.17	.17	.17	.17	.17	.17	.17	.18	.18	.18	.18	.19	.20
1.6	.26	.26	.26	.26	.26	.26	.26	.26	.26	.25	.25	.25	.24
1.8	.34	.34	.34	.34	.34	.34	.33	.33	.32	.32	.31	.29	.27
2.0	.38	.38	.37	.37	.37	.37	.36	.36	.35	.34	.33	.31	.29
2.2	.40	.40	.40	.39	.39	.39	.39	.38	.37	.37	.35	.33	.30
2.5	.42	.42	.42	.41	.41	.41	.40	.40	.39	.38	.37	.34	.31
3.0	.44	.44	.44	.43	.43	.43	.42	.42	.41	.40	.39	.36	.33
4.0	.47	.46	.46	.46	.45	.45	.45	.44	.43	.42	.41	.37	.34
5.0	.48	.48	.47	.47	.47	.46	.46	.45	.45	.44	.42	.38	.35
10.0	.49	.48	.48	.48	.48	.47	.47	.46	.46	.45	.43	.40	.36
∞	.49	.49	.48	.48	.48	.47	.47	.47	.46	.45	.44	.41	.38

Entrance Losses (k_e)

Entrance losses can be estimated using the entrance loss coefficients in Table 5.4 (FHWA 1985) and Equation 5.6.

$$H_e = k_e (v)^2/2g \qquad \text{Equation 5.6}$$

Table 5.4: Values of k_e for Culverts, Outlet Controls, and Full or Partly Full Entrances

Type of *Structure and Design of Entrance*	*Coefficent k_e*
Pipe, Concrete	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end)	0.2
Square-edge	0.5
Rounded (radius = 1/12D)	0.2
Mitered to conform to fill slope	0.7
*End-section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° levels	0.2
Side- or slope-tapered inlet	0.2
Pine, or Pipe-Arch, Corrugated Metal	
Projecting from fill (no headwal)	0.9
Headwall or headwall and wingwalls square-edge	0.5
Mitered to conform to fill slope, paved or unpaved slope	0.7
*End-section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of 1/12 barrel dimension, or beveled edges on 3 sides	0.2
Wingwalls at 30° to 75° to barrel	
Square-edged at crown	0.4
Crown edge rounded to radius of 1/2 barrel dimension, or beveled top edge	0.2
Wingwall at 10° to 25° to barrel	
Square-edged at crown	0.5
Wingwalls parallel (extension of sides)	
Square-edged at crown	0.7
Side- or slope-tapered inlet	0.2

*Note: "End-section conforming to fill slope," made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both *inlet* and *outlet* control. Some end sections, incorporating a *closed* taper in their design have a superior hydraulic performance.

Source: FHWA 1985

Manhole and Junction Losses

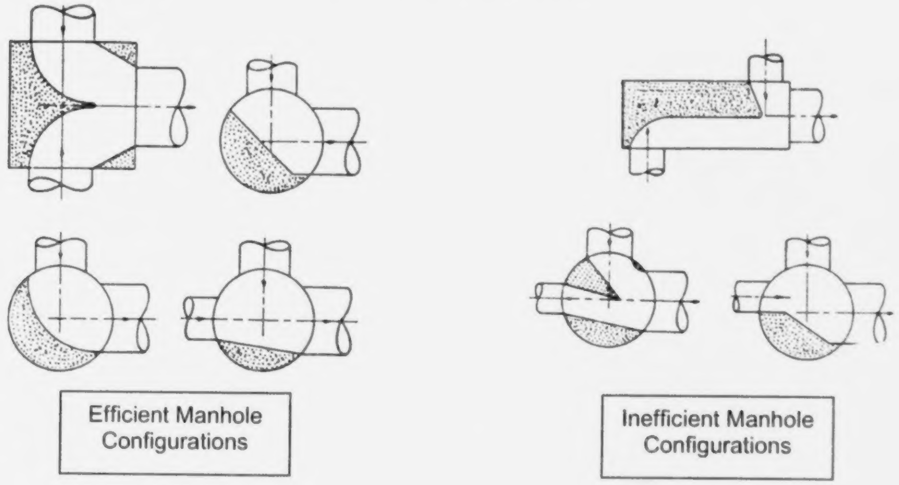
Junctions are locations where two or more pipes join together to form another pipe or channel. They represent critical points in terms of design; multiple pipes coming together at a junction should flow together smoothly to avoid high head losses. Losses at junction manholes can typically account for 20-30% of total head losses, though wide variances are possible. Careful design and construction can minimize losses.

In a three junction study by Marsalek, the following was found:

- In pressurized flow the most important flow variable was the relative lateral inflow for junctions with more than two pipes. The losses increased as the ratio of the lateral discharge to main line discharge increased.
- The important junction geometrical parameters are relative pipe sizes, junction benching, and pipe alignment. Base shape and relative manhole sizes were less important.
- In junctions where two lateral inflows occurred, head losses increased as the difference in flows between the two laterals increased. Head loss was minimized when lateral flows were equal.
- Full benching to the crown of the pipe significantly reduced losses compared to half pipe benching or no benching.

a) Deflectors

Efficient and inefficient manhole configurations are illustrated in Figure 5.3 (Urban Drainage and Flood Control District, 1984).

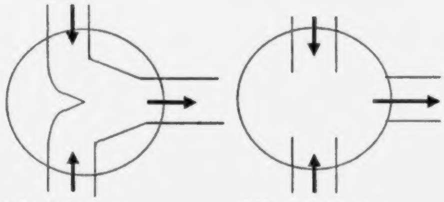


Efficient Manhole Configurations

Inefficient Manhole Configurations

Figure 5.3: Manhole Configurations

For junctions with inlets at or near right angles, the head loss coefficient varies depending on whether the incoming flow is deflected or if the incoming flows impinge. When a deflector the full height and width of the incoming pipes is used, there is less head loss.

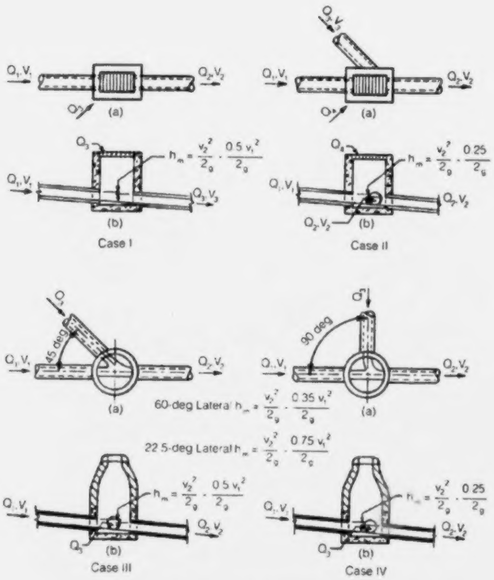

With Deflector
$K_L = 1.0$
Without Deflector
$K_L = 1.5$

Source:
City of Edmonton, 1999

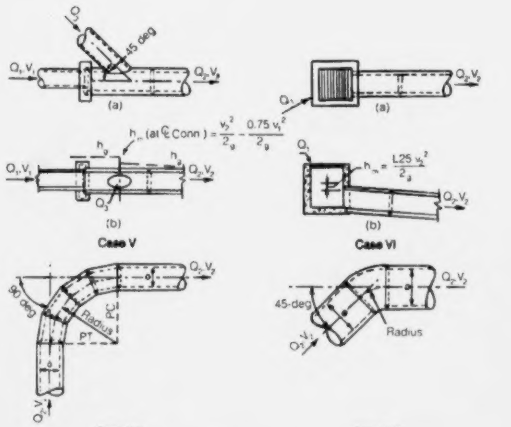
b) Alignment

Pipe alignment is also an important parameter. Figure 5.4 illustrates the head loss coefficients for different alignments.

Figure 5.4: Losses Due to Turbulence at Manholes


Q_1,V_1
Q_2,V_2
Q_3
(a)
Q_3
$h_m = \frac{v_2^2}{2_g} - \frac{0.5\,v_1^2}{2_g}$
Q_1,V_1
Q_3,V_3
(b)
Case I
Q_4
$h_m = \frac{v_2^2}{2_g} - \frac{0.25}{2_g}$
Q_2,V_2
Case II
45 deg
90 deg
60-deg Lateral $h_m = \frac{v_2^2}{2_g} - \frac{0.35\,v_1^2}{2_g}$
22.5-deg Lateral $h_m = \frac{v_2^2}{2_g} - \frac{0.75\,v_1^2}{2_g}$
Case III
Case IV

Minor head losses due to turbulence at structures: case I—inlet on main line (a) plan and (b) section, case II—inlet on main line with branch lateral (a) plan and (b) section, case III—manhole on main line with 45-deg branch lateral (a) pl and (b) section, and case IV—manhole on main line with 9t deg branch lateral (a) plan and (b) section (City of Austin, 1987).


Q_1,V_1
Q_2,V_2
Q_3
45 deg
(a)
h_m (at ℄ Conn.) $= \frac{v_2^2}{2_g} - \frac{0.75\,v_1^2}{2_g}$
$h_m = \frac{1.25\,v_2^2}{2_g}$
(b)
Case V
Case VI
90 deg
Radius
PC
PT
45-deg
Radius

Case VII

Head loss applied at PC for length of curve

Radius = diam. of pipe $h_m = 0.50 \frac{v_2^2}{2_g}$

Radius = (2-8) diam. of pipe $h_m = 0.25 \frac{v_2^2}{2_g}$

Radius = (8-20) diam. of pipe $h_m = 0.40 \frac{v_2^2}{2_g}$

Radius = greater than 20 diam. of pipe $h_m = 0$

When curves other than 90 deg are used, apply the following factors to 90-deg curves:
60-deg curve 85%,
45-deg curve 70%, and
22.5-deg curve 40%

Case VIII

Head loss applied at beginning of bend

90-deg bend $h_m = 0.50 \frac{v_2^2}{2_g}$

60-deg bend $h_m = 0.43 \frac{v_2^2}{2_g}$

45-deg bend $h_m = 0.35 \frac{v_2^2}{2_g}$

22.5-deg bend $h_m = 0.20 \frac{v_2^2}{2_g}$

Minor head losses due to turbulence at structures: case V—45-deg Wye connection or cut in (a) plan and (b) section, case VI—inlet or manhole at beginning of line (a) plan and (b) section, case VII—conduit on 90-deg curves, and case VIII—bends where radius is equal to diameter of pipe (City of Austin, 1987).

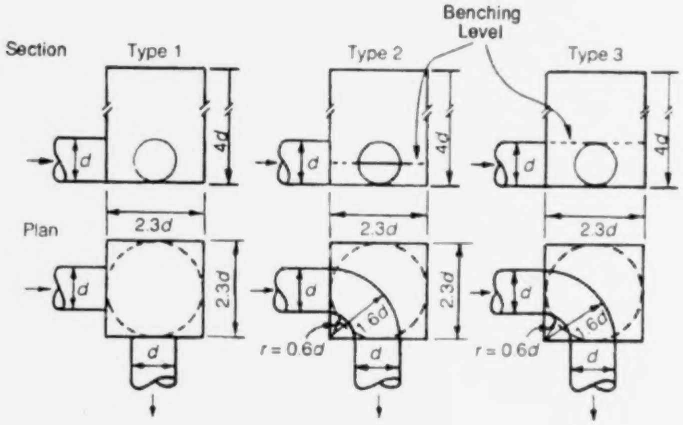
Source: City of Austin, 1987

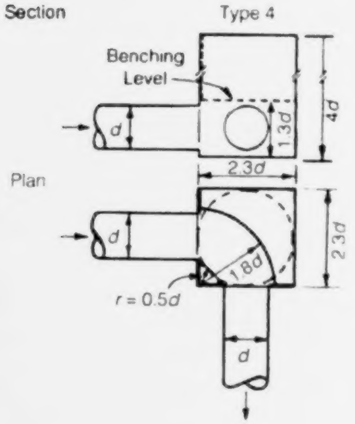
In a straight through manhole where there is no change in pipe size, the head losses are estimated by $H_m=0.05\ (v^2)/2g$. For radiused pipes and manholes with curved deflectors, see Bend Losses.

c) Benching

Benching is an important parameter. In a study by Marsalek, benching had the most pronounced effect on head loss (see Figure 5.5). Full pipe benching is recommended for manholes with a 90^0 bend.

Figure 5.5: Head Loss Coefficient Values for Benching


Benching Level
Section
Type 1
Type 2
Type 3
4d
d
Plan
2.3d
2.3d
1.6d
r = 0.6d
d


Section
Type 4
Benching Level
d
1.3d
4d
Plan
2.3d
2.3d
1.8d
r = 0.5d

Head Loss Coefficients for Clean-outs with 90-deg Bends

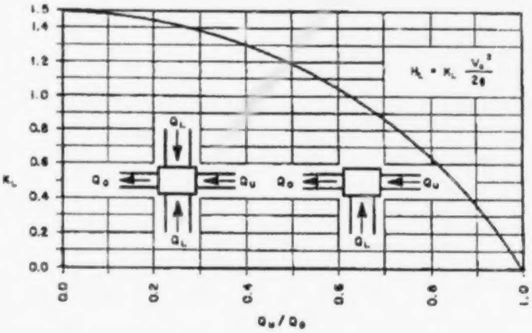
Head Loss Coefficient K_c

Benching (Type)	$W/d = 2.3$	$W/d = 4.6$
1	1.7	1.8
2	1.6	1.7
3	1.0	1.2
4	1.0	1.1

Source: Marsalek, 1985

d) Lateral Inflow

In pressurized flow, the relative lateral inflow for juctions with more than two pipes is important. Lateral inflow losses are illustrated as follows:



Source:
City of Edmonton, 1999

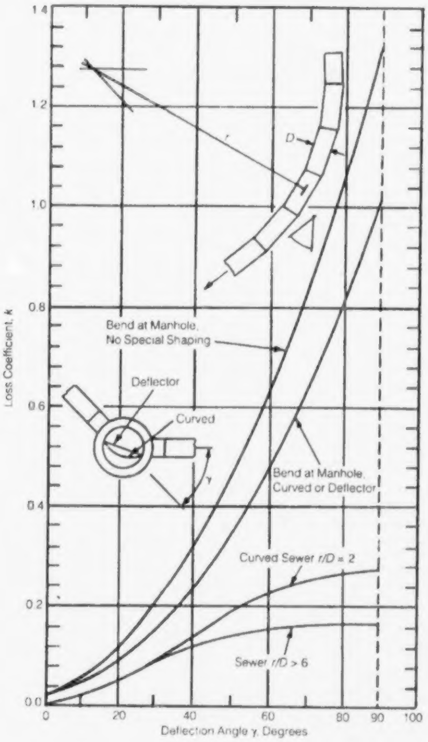
Bend Losses (K_b)

Bend losses can be estimated with equation 5.7:

$$H_b = K_b (v)^2/2g \qquad \textbf{Equation 5.7}$$

Bend losses in pipes can be estimated using the bend loss coefficients in Figure 5.6.

Figure 5.6: Values of K_b for Bends and Radiuses (AISI 1985)



5.4 Special Structures

Special structures such as special inlets, culverts, outfalls, energy dissipators, drop structures and outlet structures require careful hydraulic design consideration to ensure that they function properly. It is the responsibility of the designer or consultant to ensure the structures are properly designed. Reference material should be consulted for more information. All special structures are subject to approval by Wastewater & Drainage.

5.5 Stage-Discharge Curves

A stage-discharge (performance) curve defines the relationship between the depth of water and the discharge (outflow) from a stormwater storage facility. Stormwater ponds will typically have a principal and an emergency outlet. The principal outlet is designed to convey the design flows without allowing flow to enter the emergency spillway. The structure for the principal outlet (commonly called an outlet or control structure) often consists of an orifice, weir, or other hydraulic control device. The following information provides general design relationships for typical outlet controls. Appropriate reference material must consulted for further information or for items not listed (ie. flap gates).

Orifices

For a single orifice, flow is determined by the following equation:

$$\mathbf{Q = C_0A_0\,(2gH_0)^{0.5}} \qquad \textbf{Equation 5.8}$$

where:
Q = orifice flow rate (m^3/s)
C_0 = discharge coefficient (0.4-0.6)
A_0 = area of orifice (m^2)
H_0 = effective head on the orifice measured from the centroid of the opening (m)
g = acceleration due to gravity (9.81 m/s^2)

If the orifice discharges as a free outfall, the effective head is measured from the centreline of the orifice to the upstream water surface elevation. If the orifice is submerged, the effective head is the difference in elevation of the upstream and downstream water elevations.

A discharge coefficient of 0.6 is typically used for sharp-edged, uniform orifice entrance conditions.

Weirs

A weir is often used in the control structure as an alternate emergency spill in the case of orifice blockage. Equations for the sharp crested and broad crested weirs are as follows:

Sharp Crested:

$$Q = C_{scw} L H^{1.5} \qquad \textbf{Equation 5.9}$$

where:
Q = discharge (m^3/s)
L = horizontal weir length (m)
H = head above weir crest excluding velocity head (m)
H_c = height of weir (m)
C_{scw} = $1.81 + 0.22\,(H/H_c)$

Sharp crested weirs will be affected by submergence when the tailwater rises above the weir crest elevation. Smith (Hydraulic Structures, 1985) suggests a value of 1.837 for C_{scw}.

Broad Crested:

$$Q = C_{bcw} L H^{1.5} \qquad \textbf{Equation 5.10}$$

where:
Q = discharge (m^3/s)
L = broad crested weir length (m)
H = head above weir crest (m)
C_{bcw} = broad crested weir coefficient (1.44-1.70)

Smith (Hydraulic Structures, 1985) suggests a value of 1.705 for C_{bcw}.

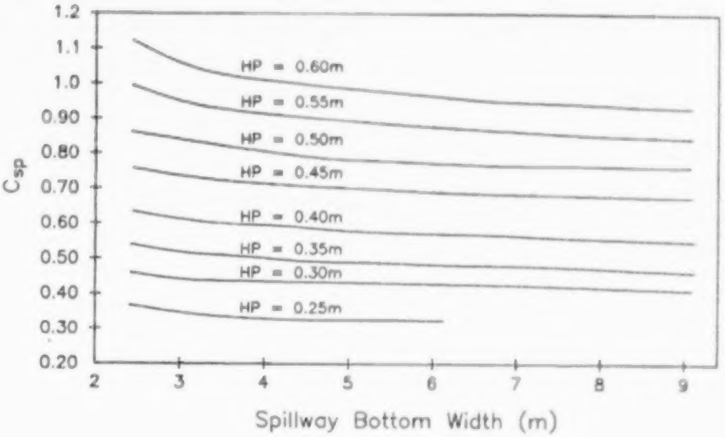
Emergency Spillway

The overland emergency spillway provides an alternate source of discharge from the stormwater pond. The discharge through a broad crested emergency spillway is:

$$Q = C_{sp}\, b\, H_p^{0.5} \qquad \textbf{Equation 5.11}$$

where:
Q = discharge (m^3/s)
C_{sp} = discharge coefficient
b = bottom width of the emergency spillway (m)
H_p = effective head on the emergency spillway (m)

The discharge coefficient, C_{sp}[1] is a function of the spillway bottom width and effective head.



5.6 Technical Requirements

5.6.1 Submission

i. Energy losses must be properly accounted for in the design of the storm sewer system. Head losses are controlled by both flow characteristics and junction geometry. These losses should be used to determine EGL and HGL elevations. It is the designer or consultant's responsibility to ensure the system functions hydraulically, otherwise unacceptable surcharging and flooding may occur. The above information and other appropriate reference material must be used in the design.

ii. HGL calculations (and hydraulic designs) must be submitted for the following situations:

- Areas where backwater affects from stormwater ponds at the HWL cause storm sewer surcharge conditions. The lowest top of footing elevation must be a minimum of 0.3m above the HGL elevation. Surcharge to ground surface is strictly prohibited. Hand calculations or EXTRAN computer modelling (when carefully used) are acceptable methods for determining HGLs.
- Large diameter pipe with 90^0 (or similar) bends or junctions. Large diameter pipe is defined as pipe larger than 750 mm diameter.
- Pipe transitions from large diameter to small diameter
- Trunk slopes changing from steep to flat
- Special structures as requested by Wastewater & Drainage

---

[1] U.S. Department of Transportation, *"Urban Drainage Design Manual-Hydraulic Circular No. 22"*, FHWA-SA-96-078

5.6.2 Design

i. Efficient manhole or junction designs should be used. Junctions with two opposed incoming laterals must be carefully designed. Generally, high head losses result when there is uneven distribution of the lateral inflows: lower losses result when the lateral inflows are comparable.

ii. Sudden extreme changes in direction should be avoided for large flows and high velocities.

iii. The use of bends and curved pipe is recommended to provide smoother hydraulics.

- The ratio of the radius of the bend r (measured to the centreline of the pipe) to the pipe's inside diameter D, should be ≥ 2. See Figure 5.6.
- For r/D ratios < 2, the maximum bend deflection should be 45^0.

iv. For manholes with a 90^0 bend, **full benching** to the crown of the pipe is required to reduce energy head losses. Half pipe benching is not as effective. Details and/or requirements must be indicated on the construction drawings.

v. A minimum drop of 30 mm is required in a through manhole where there is no change in pipe diameter. A minimum drop of 60 mm is required in a bend where there is no change in pipe diameter.

vi. Design considerations which can help overcome hydraulic concerns may include, but are not limited to:

- Increase pipe size
- Provide manhole benching at 90^0 bends. Full pipe benching is recommended.
- Provide proper aeration and venting
- Install manhole drops (which act as energy dissipators) to reduce steep grades and high velocities
- Use curved pipe and/or bends
- Smooth transition entrances

vii. All storm pipe shall be rubber gasketed, except where approved otherwise by Wastewater & Drainage.

6.0 Stormwater Ponds

6.1 General

Stormwater facilities (ponds) receive stormwater runoff from conveyance systems (ditches, roads, storm sewer) and discharge at pre-determined rates to receiving waters. Discharge rates are determined as part of the Master Drainage Plan or Staged Master Drainage Plan reports. The purpose of the facilities is to provide temporary storage of stormwater and water quality enhancement prior to discharge. Stormwater facilities include dry ponds, wet ponds, and wetlands, or a combination of these. As well, these facilities are also types of end-of-pipe (or treatment) Best Management Practices (BMPs). Selection of a facility type is a function of quantity control, water quality and erosion control.

Detailed pond design philosophies are described further in **Sections 6.2, 6.3 and 6.4**. Design criteria is a compilation of Alberta Environment's "Stormwater Management Guidelines for the Province of Alberta" (January 1999) and the City of Calgary's criteria. Where design criteria between the province and the City varies, the more stringent design criteria shall govern.

All stormwater ponds (ie. dry ponds, wet ponds, and wetlands) require the appropriate approvals from Wastewater & Drainage and Alberta Environment prior to construction. Pursuant to the Environmental Protection and Enhancement Act (EPEA), approval is required for the construction of all stormwater ponds. The consultant is responsible for preparing and submitting the information to Wastewater & Drainage. Wastewater & Drainage will apply for approval to Alberta Environment. A 30 day public notification period is required. Refer to **Appendix A** for required information. For more information, see **Section 2.0 Approvals & Processes**.

6.1.1 Terminology

It is important that the terminology used is understood properly, given the vast amount of information available. A combination of facility types may also be considered.

i. Detention Storage

Detention storage refers to the temporary storage and gradual release of stormwater in a storage element. There is little or no infiltration of the stored stormwater. The main purpose of detention storage is to provide quantity control by attenuating runoff. Dry ponds, wet ponds, and wetlands are the most common types of detention storage.

ii. Retention Storage

True retention storage refers to the collection and storage of runoff for a considerable length of time, whereby release is by evaporation, transpiration or infiltration. Retention facilities that provide for the slow release of stormwater over an extended period of several days are often referred to as extended detention facilities. Retention facilities are typically designed to provide dual functions of stormwater quantity and quality control. Infiltration ponds and evaporation ponds are examples of retention facilities.

Although the terms detention, retention and extended detention have true definitions, they are often used interchangeably.

iii. Extended Detention Storage

Extended detention storage refers to the active or live storage area in a stormwater facility. The area is subject to the frequent wetting from storm events. The area is generally delineated as the land between the pond bottom and the high water elevation HWL for a dry pond, and the area between the PWL and HWL for wet ponds and wetlands.

iv. In-line Storage

In-line storage refers to storage that is constructed directly on (or on the same alignment as) the minor conveyance system. It also includes storage elements formed by construction of an embankment across a natural or existing watercourse. In general, these types of facilities are discouraged.

v. Off-line Storage

Off-line storage occurs when the minor conveyance system conducts flows to an outlet with restricted discharge. The peak flows, over and above the carrying capacity of the conveyance system, are then routed to storage facilities such as ponds, tanks or basins. These storage facilities do not form part of the subsurface system.

vi. Permanent Pool

The permanent pool is the portion of a stormwater pond which retains a permanent volume and depth of water. All wet ponds and wetlands will have a permanent water elevation delineated as PWL. This term is also commonly known as the normal water level (NWL).

The permanent pool acts as a buffer by slowing down stormwater entering the pond and trapping pollutants. Thus, the permanent pool is the pond's primary source of water quality enhancement.

vii. Sediment Forebay

A sediment forebay is a permanent pool that is designed to facilitate maintenance and improve pollutant removal by trapping larger particles near the inlet of the pond. The forebay is often designed to be the deepest area of the pond to minimize the potential for particle re-suspension and prevent conveyance of the suspended material to the outlet. It is important that the sediment forebay be properly sized.

viii. Active Storage

Active storage is the temporary or dry storage (volume) provided in a stormwater pond. In a dry pond, this is the storage between the bottom of the pond and the HWL. In a wet pond and a wetland, this is the storage between PWL (or NWL) and HWL.

ix. Wet Pond-Wetland/Hybrid Wet Pond-Wetland/Other Hybrid Ponds

Although wet ponds and wetlands have many common design elements, the distinction between a wet pond and a wetland may be difficult to differentiate. The main criteria used to differentiate between the two is the vegetation design and the proportion of deep (> 0.5 m) and shallow areas. A wet pond has a greater portion of deep water zones (generally 2.0 to 3.0 m), and aquatic vegetation is concentrated along the perimeter of the pond. Conversely, wetlands are dominated by shallow water zones, and vegetation is found throughout the pond. A hybrid wet pond-wetland uses both shallow and deep water zones. Other hybrid ponds can include combinations of stormwater ponds.

6.1.2 Level of Service

Stormwater ponds must be designed to provide adequate flood protection (storage volume for quantity control) and water quality (as required). **All stormwater facilities must be designed to provide active storage for a 1 in 100 year return period storm (see Section 3.0 Stormwater Design). For water quality, the pond must also be sized to provide a minimum 80% removal of Total Suspended Solids for particle sizes ≥75μm. The more conservative volume of the two criteria shall dominate. As well, minimum permanent and active storage volumes equal to 25 mm over the entire catchment area (25 mm x area) are required for water quality for wet ponds.** A minimum detention time of 24 hours must also be provided for wet ponds and wetlands. Refer to **Sections 6.2**, **6.3** and **6.4** for more detailed information on sizing requirements.

A lower level of service may be allowed for **retrofit** facilities subject to approval from Wastewater & Drainage.

6.1.3 Overland Drainage Routes

i. Overland drainage routes that direct flows from the 100 year storm event to the pond area shall be provided. Overland flow design velocities (v) and depths (d) must be in accordance with "Stormwater Management Guidelines" for the Province of Alberta (January 1999). See **Table 3.15 and Figure 3.9**. Erosion control needs must be evaluated.

ii. An emergency overland escape route from all ponds is to be provided. In general, the escape route must provide a minimum capacity between 1 and 2 m^3/s. Appropriate capacity should be determined at the time of design.

Optionally, additional freeboard may be considered in cases where it is difficult to establish an escape route. The additional freeboard would provide a higher level of service overall.

iii. Sanitary sewer manholes must be located outside of impoundment (pond) areas. Whenever possible, sanitary sewer manholes should not be located within the overland drainage route.

iv. Sanitary sewer manholes located within overland drainage routes must be sealed. Bolting is at the discretion of Wastewater & Drainage.

6.1.4 Vegetation Use

Vegetation is an important component in the design of stormwater ponds. Design and use of vegetation should only be undertaken by qualified consultants. See **Appendix E** for suitable plant species. The selection of vegetation should consider the following:

Slope Stabilization

The root systems of many tree, shrub and plant species help bind soils to provide resistance to erosion. Suitable planting schemes should be selected to provide long-term stability.

Temperature Mitigation

Through shading, the location of deciduous and coniferous trees along the edges of wet ponds and wetlands can contribute to the mitigation of water temperature increases. Water depth can also impact temperature.

Waterfowl Deterrence

The establishment of a dense band of woody vegetation around the perimeter of wet ponds and wetlands can deter undesirable species of waterfowl. Colonization by waterfowl such as geese, can lead to fecal contamination of the water in the ponds.

Public Access Mitigation

Suitable shrubs and vegetation can create an effective barrier to deter the public from accessing pond areas, steep slopes, and structures that are potentially hazardous.

Enhancement and Aesthetic Benefits

Vegetation can create visual buffers, enhance views and contribute to the character and enhancement of a development. Consideration should be given to the requirements of the users, recreational requirements, and public safety.

Others

Vegetation may be used to filter sediments, trap floatables, and conceal structures and fencing.

6.1.5 Water Quality

Dry ponds typically do not provide water quality improvement unless detention time is considerable and/or sediment forebays are installed. However, wet ponds and wetlands are considered appropriate facilities for providing water quality enhancement. All wet ponds and wetlands must be designed to meet the water quality standards described in **Sections 6.3.2.7** and **6.4.2.7** and **Section 7.0 Water Quality**.

6.1.6 Geotechnical

A geotechnical report must be undertaken by a qualified geotechnical consultant that addresses issues related to the design of all stormwater ponds (wet ponds and wetlands, and dry ponds if requested). The purpose of the report is to determine criteria such as subdrainage design, liner requirements (infiltration), and special design conditions such as slope stability (particularly for sites classified as a dam). For ponds requiring a liner, preference should be given to using clay where possible or an acceptable alternative; puncturing of liner materials during sediment removal is a concern.

The report must be submitted and approved by Wastewater & Drainage prior to submission of the construction drawings. The geotechnical report should be submitted with the Stormwater Pond report, the Master Drainage Plan report, or the Staged Master Drainage Plan report, whichever is the most practicable. Required details must be indicated on the construction drawings.

Geotechnical reports shall be submitted to Alberta Environment, Municipal Approvals, at the pre-design stage for stormwater ponds that may be classified as a dam (see **Section 2.3.3.1**); approval under the Water Act is required. Drawings of the pond shall also be submitted. Municipal Approvals will forward the information to the Dam Safety and Water Projects Branch as part of the review process. Contact Alberta Environment, Municipal Approvals for more information.

6.1.7 Signage

All ponds are required to have appropriate signage. Signage is required at all entrances to the pond and at any other critical points. Locations should be identified on the Site/Overall pond drawing. See **Appendix D** for sign requirements. The developer is responsible for the cost of purchasing and installation. Arrangements can be made with Wastewater & Drainage (Systems Maintenance) to order and/or install the signs.

Signs promoting public education are encouraged. Signs may include information regarding operation and purpose of the pond, protection of the environment, water conservation, native landscaping, impact of chemicals and interpretative trails. Contact Wastewater & Drainage and/or Park Development & Operations for more information.

6.1.8 Operating and Maintenance Manual

To ensure that the designed stormwater pond is operated and maintained properly, an operating and maintenance manual is required for all dry ponds, wet ponds and wetland facilities. The manual is to be prepared by the owner/developer, or his designated consultant. The manual shall contain the following:

- List of additional mechanical and electrical equipment used in the design of the facility. This shall include equipment/part lists, manufacturer's operation requirements, maintenance, service and repair instructions, and warranties
- Outline of normal expected operational requirements
- Outline of emergency operating requirements
- Long term and short term maintenance requirements for vegetation

Wastewater & Drainage will forward a copy of the manual to the Systems Maintenance group who is responsible for maintenance.

6.1.9 Monitoring System

Remote water level monitoring equipment is required at all ponds to allow monitoring by Wastewater & Drainage staff (Systems Maintenance and Design) when the pond is being used for storage. The equipment shall be installed at the developer's expense. Refer to **Appendix C** for information on monitoring equipment requirements.

6.1.9.1 Equipment

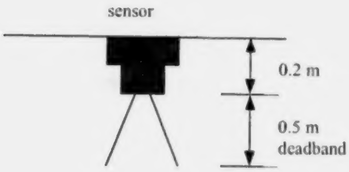
A copy of the latest specification is available on computer file. Contact the Stormwater Engineer at Wastewater & Drainage for further information. **The equipment identified in the specifications must be used**; other equipment may not be compatible.

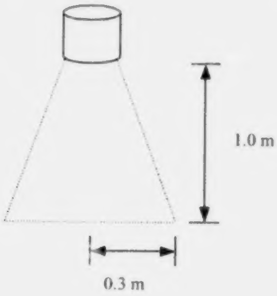
The monitoring equipment consists of a sonic sensor, autodialler, and datalogger which are tied into an annunciator system at the City of Calgary Engineering Emergency Communication Center 101 (EECC) at Manchester yards.

Sonic Sensor

The sonic sensor is typically mounted in the control structure on the upstream side. As an alternative for wet ponds and wetlands, a stilling well manhole may be installed adjacent to the pond to house the monitoring equipment. The sensor measures the level of the water in the structure, which relates back to the level of water in the pond. The sensor must also be set up for the following elevations: low water level (LWL) in a dry pond, or the normal (permanent) water level (NWL) in a wet pond-wetland, and the high water level (HWL). The low water level is the bottom elevation in a dry pond. Once these levels have been reached, an alarm is sent to EECC.

In order to operate properly, a deadband of 0.5 m is required for the sensor (see diagram below). This is the distance between the bottom of the sensor and the highest recordable elevation (or depth) required, which is usually the HWL. Where possible, the HWL elevation should be set below the required deadband to provide additional clearance.





Due to the conical shape of the sensor band, it is important that there be sufficient radial clearance (see above diagram) between the signal from the sensor and any structure wall or protrusions. A radial distance of 0.3 m per 1 m of vertical distance is required. Ensure that manhole rungs, trash racks, etc. do not interfere with the signal.

As a backup to the sonic sensor, a mechanical float (Flygt bulb) is installed at or just below the HWL elevation.

Autodialler

The autodialler is also a critical component of the monitoring system. There are 5 conditions that must be programmed into the autodialler:

- LWL (pond bottom) elevation for dry ponds, and NWL (plus 0.1m) for wet ponds/wetlands
- HWL elevation
- Flygt bulb set at HWL
- Loss of power
- Intrusion alarm

When any one of these conditions is encountered, the autodialler remotely accesses the annunciator system at EECC, and an alarm is catalogued. Systems Maintenance staff from Wastewater & Drainage then attend to the alarm(s).

Datalogger

The datalogger allows the cataloguing and storage of recorded water levels. Design staff at Wastewater & Drainage are able to access this information for analyses by remote telemetry. Typically, the dataloggers have 32K of memory.

Annunciator

The annunciator system is located at the City of Calgary Engineering Emergency Communication Center (EECC). All of the ponds that are ultimately owned by the City of Calgary are connected to the annunciator. Programming of the pond into the annunciator must be done by the service provider contracted by Wastewater & Drainage. The service contractor is currently Simark Controls Ltd. in Calgary.

6.1.9.2 Setup and Calibration

Due to the complexity of the equipment, setup must be completed by a qualified contractor. A calibration certificate is also required to ensure that the elevations (HWL, NWL, and pond bottom) have been set correctly. Calibration must be undertaken as a joint effort between the City's service provider (currently Simark Controls Ltd.) and Lakewood Systems Ltd. (Edmonton, AB). City personnel then use this information to create the required format files. Calibration certificates and phone numbers must be submitted to Wastewater & Drainage. Monitoring equipment should be operational prior to CCC; delays in servicing of phone and electrical lines must be approved by Wastewater & Drainage.

6.1.9.3 Alarms

Once the monitoring equipment has been set up and calibrated, Systems Maintenance personnel from Wastewater & Drainage will respond to any alarms that come through. Wastewater & Drainage will also be responsible for securing the site during the period of inundation. However, during the maintenance period, if any of the alarms are due to maintenance problems, vandalism, telecommunication problems, etc., the developer/consultant will be contacted. It is the developer's responsibility to fix any problems during the maintenance period.

6.1.10 Maintenance Periods

For additional information, also refer to **Section 11.0** and **Appendix J**.

6.1.10.1 Staged Construction

Staged construction is not permitted for dry ponds. Staged construction will be considered for wet ponds and wetlands, depending on the size of the drainage area. Small facilities should be constructed in entirety. Wastewater & Drainage must approve any proposed staged construction. (Please note that any expansions to stormwater ponds require an amending approval from Alberta Environment.)

Where staged construction is permitted, the final acceptance certificate (FAC) will not be issued until the required maintenance period has been met after the last phase of staged construction.

Separate approval for staged construction of landscaping must be approved by Park Development & Operations.

6.1.10.2 Dry Ponds & Wet Ponds

i. Construction Completion Certificate (CCC)

The CCC will only be issued after the required as-builts for the pond have been submitted and approved by Wastewater & Drainage. Any requests for omissions must be accompanied by a letter of intent indicating the proposed installation date.

A separate CCC must also be issued by Park Development & Operations, primarily for grading, loaming, seeding and landscaping. Some of these items are also included in the CCC issued by Wastewater & Drainage.

ii. Final Acceptance Certificate (FAC)

A maintenance period of 3 years is required on all wet ponds and dry ponds. During this time, the developer is responsible for any maintenance associated with the pond, and all electrical and telephone bills. Prior to the City taking over the pond, sediment removal must be completed. Once the FAC has been issued, Wastewater & Drainage will assume all responsibility for the pond and utility bills.

A separate FAC must also be issued by Park Development & Operations, primarily for grading, loaming, seeding and landscaping. Some of these items are also included in the FAC issued by Wastewater & Drainage.

6.1.10.3 Wetlands

i. Construction Completion Certificate (CCC)

The CCC will only be issued after the required as-builts for the wetland have been submitted and approved by Wastewater & Drainage. Any requests for omissions must be accompanied by a letter of intent indicating the proposed installation date.

A separate CCC must also be issued by Park Development & Operations, primarily for grading, loaming, seeding and landscaping. Some of these items are also included in the CCC issued by Wastewater & Drainage.

ii. Final Acceptance Certificate (FAC)

A maintenance period of 5 years is required on all wetlands. During this time, the developer is responsible for any maintenance associated with the pond, and all electrical and telephone bills. Once the FAC has been issued, Wastewater & Drainage will assume all responsibility for the pond and utility bills.

A separate FAC must also be issued by Park Development & Operations, primarily for grading, loaming, seeding and landscaping.

Some of these items are also included in the FAC issued by Wastewater & Drainage.

6.1.10.4 Automatic Control Gates

i. Construction Completion Certificate (CCC)

The CCC will only be issued after the required as-builts for the gates have been submitted and approved by Wastewater & Drainage. Requests for omissions will not be permitted. An Operations Manual must also be submitted.

ii. Final Acceptance Certificate (FAC)

A maintenance period of 5 years is required on all automatic control gate systems. During this time, the developer is responsible for any maintenance associated with the gates, and all electrical and telephone bills. Once the FAC has been issued, Wastewater & Drainage will assume all responsibility for the gates and utility bills.

6.2 Dry Ponds

6.2.1 Introduction

Dry ponds are impoundment areas used to temporarily store stormwater runoff in order to restrict downstream discharge to predetermined levels, to reduce downstream flooding and erosion potential. Usually they are incorporated as multi-purpose facilities.

Dry ponds may be constructed by an embankment or through excavation of a depression. Most typical dry ponds have no permanent pool of water. As a result, they can be effectively used for erosion control and quantity control. Generally, dry ponds are not intended as water improvement facilities. However, water quality enhancement can be achieved through the use of sediment forebays that include a permanent pool.

Dry ponds may be applied where topographic or planning constraints exist that limit the implementation of wet ponds or wetlands. Although water quality requirements will prompt more construction of wet ponds and wetlands than dry ponds, dry ponds still have a place in the stormwater drainage system. Use of dry ponds is appropriate for retrofit projects where water depth is an issue, areas where dry recreational or passive use is required, or where water quality can be implemented in a downstream wet pond or wetland.

6.2.2 Design

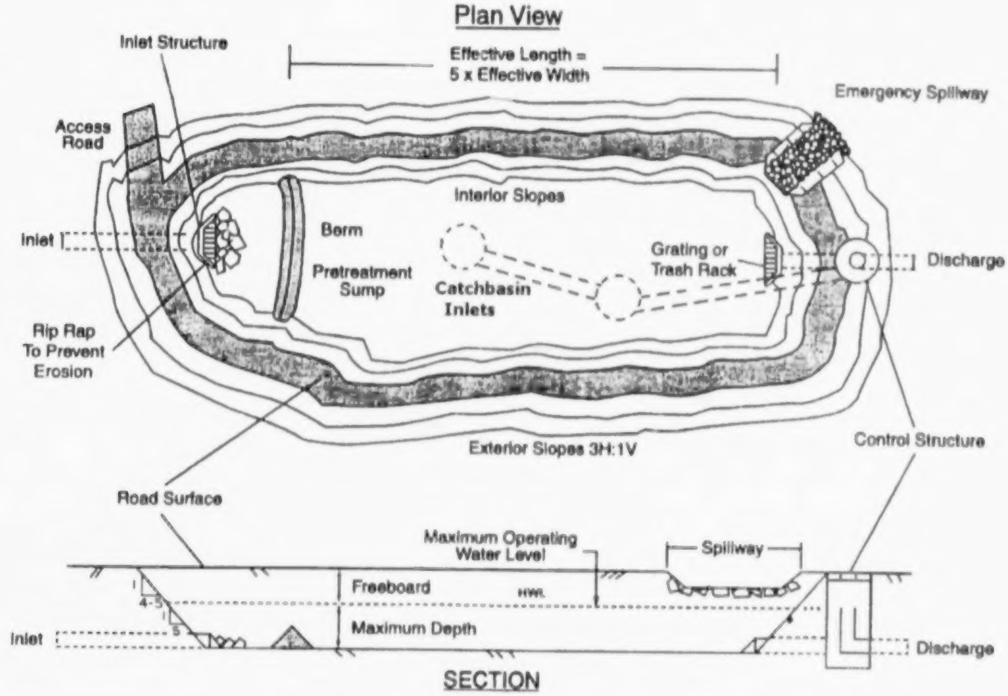

Plan View
Inlet Structure
Effective Length = 5 x Effective Width
Emergency Spillway
Access Road
Interior Slopes
Inlet
Berm
Pretreatment Sump
Catchbasin Inlets
Grating or Trash Rack
Discharge
Rip Rap To Prevent Erosion
Exterior Slopes 3H:1V
Control Structure
Road Surface
Maximum Operating Water Level
Spillway
Freeboard
HWL
4-5
1
5
Maximum Depth
Inlet
Discharge
SECTION

Figure 6.1: Dry Pond with Forebay

Table 6.1: Design Summary Guide for Dry Ponds

Design Element	Design Objective	Minimum Criteria	Recommended Criteria
Level of Service/ Volumetric Sizing	Provision of appropriate level of protection and adequate volume	100 year design	
Land Dedication	Appropriate location	MR, PUL, non-significant ER, MSR	MR, PUL, non-significant ER
Drainage Area	Function of permitted release rate. Maintain minimum orifice size, limit number of ponds, maximum pond volume	Not applicable	Not applicable
Pond Area/ Number of Ponds	Maximum pond area, Limit number of ponds	0.8 ha at HWL	
Sediment Forebay	Pre-treatment (sedimentation)	Min. depth: 1.0 m Appropriate Length and Width according to Section 6.3.2.8	Min depth: 1.5 m
Active Storage Detention Time	Suspended Solids Settling	24 hours	
Length:Width Ratio	Maximize flow path and minimize short-circuiting	Min. 3:1	4:1 to 5:1
Pond Depth	Safety	Max. 1.5 m (3 m in forebay) Freeboard: 0.15 m Min.	Max. 1.5 m (2.5 m in forebay)

Design Element	Design Objective	Minimum Criteria	Recommended Criteria
Overland Routes	Safety	Meets Alberta Environment Depth-Velocity guidelines	
Escape Route	Safety	Min. 1 to 2 m^3/s capacity	Maximum possible
HGL	To prevent backup	No surcharging to surface	HGL impact confined to pipe adjacent to pond
Landscaping	Public Amenity & Safety	Approval of Wastewater & Drainage and Park Development & Operations	
Bottom Grading	Drainage	1.5%	2.0%
Side Slopes	Safety	Max. 5H:1V for inundated area Max. 4H:1V above HWL for inward facing slopes Max. 3H:1V for outward facing slopes	
Inlet	Avoid clogging/freezing	Min. 450 mm diameter	
Catchbasins/Drain Inlets	Avoid clogging	1.2 m diameter Type 5A MH	
Gratings	Avoid clogging	Armtec Type V	
	Safety	Coated with Armaguard Size: Max. 3m x 1m per section for inlet Max. 1.5 m/s inlet velocity Bolting Required	
Outlet	Safety & Maintenance	1.2 m x 1.2 m/chamber	1.8 m x 1.8 m/chamber
Orifice	Avoid Plugging	50 mm diameter	100 mm diameter
Trash Rack	Protect Orifice from plugging	Req'd when orifice ≤ 200 mm diameter	
Gate Valve	Bypass & Maintenance	Required (300 mm diameter)	
Maintenance Vehicle Access	Access for equipment	Width: 3.0 m Turning Radius: 8 m	4.0 m
Fencing	Safety	Not generally required	
Monitoring Equipment	Safety & Design	Required (see Section 6.1.9 and Appendix C)	
Signage	Safety	Required (see Appendix D)	

Note: Refer to detailed information provided in following sections

6.2.2.1 Level of Service/Volumetric Sizing

Dry ponds must provide a storage capacity for a 100 year return period storm (see **Section 3.0 Stormwater Design**). This capacity is based on quantity control. Where possible, some detention should be provided to facilitate settling of suspended solids for dry ponds that include a sediment forebay. Refer to **Section 11.0** for **Technical Requirements**.

Release rates from the ponds must conform to the rates set out in the approved Master Drainage Plan report and/or approved Staged Master Drainage Plan report.

6.2.2.2 Land Dedication

Refer to "Calgary Open Space Plan" by Calgary Parks & Recreation (February 2000) for further information.

i. Dry ponds that are to be ultimately operated by the City of Calgary are to be located within the following:
   - Municipal Reserve (MR)
   - Public Utility Lots (PUL)
   - Non-significant Environmental Reserve (ER) as approved by Park Development & Operations.

ii. The use of Municipal School Reserve (MSR) will only be supported provided the location, size, and recreational function of the reserve is not prejudiced. Use of School Reserve (SR) is not supported.

iii. Dry ponds should not be located in Major Natural Area Parks.

iv. Dry ponds should not be located in river valleys unless there are no other viable locations.

v. Where a dry pond is located on privately owned land, an easement is required to permit encroachment of water onto the property and restrict development in the areas subject to inundation. For ponds proposed on provincial lands, contact Alberta Environment.

vi. A maintenance agreement is required for any **public (City owned)** pond that will be operated and maintained by a private owner. Contact Wastewater & Drainage for further information.

vii. The maximum level of inundation, the high water level (HWL), must not encroach onto private property. Lots bordering the dry pond are required to have abutting property elevations a minimum of 0.3 m above the spillover elevation of the pond.

6.2.2.3 Frequency of Inundation

Where possible, a low flow bypass system shall be used to minimize the frequency of inundation. Alternatively, where the high frequency of inundation cannot be altered, it is recommended that a low flow channel be constructed through the pond. Suitable vegetation along the channel must be used.

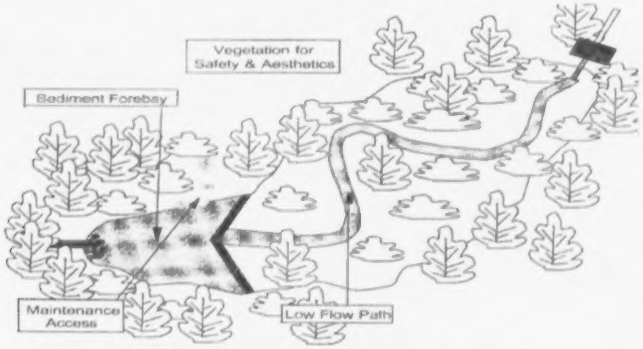


Figure 6.2: Low Flow Channel

6.2.2.4 Drainage Area

There currently is no minimum drainage area requirement. The contributing drainage area requirement for a dry pond is a function of the permitted release rate.

6.2.2.5 Pond Area & Number of Ponds

The minimum area of a dry pond shall be 0.8 ha at HWL. Smaller areas will only be considered on a site-specific basis at the discretion of Wastewater & Drainage. In such cases, the private owner may be required to enter into a private maintenance agreement.

From a maintenance perspective, economies of scale can be realized with fewer and larger ponds. The developer shall make every effort throughout the planning process to limit the number of ponds required.

6.2.2.6 Winter Operation

Dry ponds are normally the least affected by winter/spring conditions since there is typically no permanent pool. However, precautions should be taken to minimize the effects of freezing of pipes and orifices.

6.2.2.7 Sediment Forebay

In the past, most dry ponds in Calgary have not utilized sediment forebays since water quality was not typically an objective. However, a sediment forebay can be used to facilitate maintenance and provide some degree of pollutant removal for the larger sediment particles. When a forebay is included, the forebay should be 1.0 m deep or greater to minimize the potential for scour and re-suspension of sediments. The recommended minimum depth is 1.5 m. Sizing of the forebay is dependent on the inlet configuration. Refer to **Section 6.3.2.8** for sizing criteria. Sedimentation vaults may also be considered subject to approval of Wastewater & Drainage.

6.2.2.8 Forebay Berm

When a forebay is included in the design of the dry pond, an earthen berm can be used to separate the forebay from the rest of the pond. Since the downstream side of the berm will be dry, the berm should be designed as a small dam. A weir should be designed at the top of the berm to convey flows to the downstream section of the pond during storm events. The forebay can also be incorporated as a permanent pool set below the bottom elevation of the dry pond.

To facilitate cleaning of the forebay, a maintenance pipe should be installed in the berm. A valve, to open and close the pipe, should be installed on the upstream side of the pipe. Under normal operating conditions, the valve should be closed. During maintenance periods, the valve should be open to allow draining of the forebay.

Vegetation should be planted on the top of the berm to promote filtration of water as is passes over the berm. Suitable vegetation includes American bulrush and softstem bulrush. The vegetation should be planted on the forebay side of the berm at a depth no greater than 30 cm. As a secondary benefit, the vegetation will also act as a barrier to public access.

6.2.2.9 Detention Time

Where possible, a minimum detention time of 24 hours is desired to promote water quality enhancement for dry ponds. Detention time is defined as the theoretical time required to displace the contents of a stormwater pond at a given rate of discharge (ie. volume divided by rate of discharge).

6.2.2.10 Length:Width Ratio

For dry ponds with a continuous flow path, all stormwater should be conveyed to one inlet location if possible. To provide the longest flow path through the pond, the inlet should be located as far away from the outlet as possible. A pond with a length to width ratio ≥ 3:1 will have an acceptable flow path. The preferred length to width ratio ranges from 4:1 to 5:1. Effective length excludes forebay length.

For dry ponds governed by other planned uses, such as playfields, relaxation of the length to width ratio will be considered by Wastewater &

Drainage. Contact Wastewater & Drainage for more information.

6.2.2.11 Pond Depth

The **maximum** active depth for a dry pond is 1.5 m, measured from the elevation of the pond bottom to the 100 year elevation or HWL. In addition, a minimum freeboard of 0.15 m is required above HWL. The primary factor in establishing this depth restriction is concern for safety of children.

If the pond includes a sediment forebay, the depth from the bottom of the forebay to the 100 year (or HWL) elevation should not exceed 3 m. The desired overall depth is 2.5 m.

6.2.2.12 Overland Drainage Routes

i. Overland drainage routes that direct flows from the 100 year storm event to the pond area shall be provided. Overland flow design velocities (v) and depths (d) must be in accordance with "Stormwater Management Guidelines" for the Province of Alberta (January 1999). See **Table 3.15 and Figure 3.9**. Erosion control needs must be evaluated.

ii. An emergency overland escape route from all ponds is to be provided. In general, the escape route must provide a minimum capacity between 1 and 2 m^3/s. Appropriate capacity should be determined at the time of design.

Optionally, additional freeboard may be considered in cases where it is difficult to establish an escape route. The additional freeboard would provide a higher level of service overall.

iii. Sanitary sewer manholes must be located outside of impoundment (pond) areas. Whenever possible, sanitary sewer manholes should not be located within the overland drainage route.

iv. Sanitary sewer manholes located within overland drainage routes must be sealed. Bolting is at the discretion of Wastewater & Drainage.

6.2.2.13 Hydraulics

The 100 year elevation will be established taking into consideration adjacent footing elevations. When the dry pond is at the 100 year elevation, water should not back up through the storm sewer and weeping tile connections to create hydraulic pressure on foundations. Areas affected by the HWL and resulting hydraulic grade line should be kept to a minimum. Free flow conditions are preferable; this is achieved when the crown of the closest incoming storm sewer(s) is at or above the HWL. All hydraulic conditions must be approved by Wastewater & Drainage. Refer to **Section 5.0 Hydraulic Design** for more information.

When free flow conditions are not achieved based on the HWL, hydraulic grade line (HGL) elevations in the storm sewers must be determined based on the pond at HWL and the appropriate losses taken into account (ie. junction losses, pipe losses, etc.). **Surrounding lowest top of footing (or slab) elevations must be a minimum of 0.3 m above the HGL.** Other options to protecting weeping tile connections include a separate weeping tile system connected downstream of the pond, or sump pump to surface. Weeping tile connected to sanitary is not permitted in any circumstances.

Surcharging to ground surface will **not** be permitted. Contact Wastewater & Drainage for further information.

Backflow prevention devices are required on all weeping tile connections as per the Alberta Plumbing Code.

All upstream storm piping below the HWL and resulting HGL must be rubber gasketed.

6.2.2.14 Landscaping & Vegetation

Landscaping and vegetation plans must be submitted with the construction drawings. The drawings must be reviewed and approved by Wastewater & Drainage and Park Development & Operations. All landscaping must be prepared by a qualified consultant and must conform to "Development Guidelines and Standard Specifications-Landscape Construction" (latest issue) by Calgary Parks & Recreation. Refer to **Appendix E for Recommended Plant Species**.

i. General

- Playfields should be located outside of the inundation area where possible. Where playfields must be located within the pond, it is preferable to have soccer fields if possible; the shale associated with baseball diamonds tends to cause maintenance problems. Certain playfields are more suitable than others.
- Playgrounds are **not** permitted in the inundation area of the pond.
- In general, trees are to be planted above the area of inundation (HWL elevation).

- The area of inundation must be sodded to establish grass cover. Areas above the level of inundation may be seeded.

ii. Extended Detention Areas

Extended detention areas are the areas subject to the frequent wetting from storm events. The area is generally delineated as the land between the pond bottom and the high water elevation HWL for a dry pond.

Growing conditions in this area are generally harsher and plant establishment is more difficult. Hardy hydric grass should be used. When planting shrubs, only the lower branches are permitted to be inundated during a storm event.

For dry ponds that include a sediment forebay, vegetation is permitted adjacent to the forebay. As well, hydric plants may be planted in areas where there is a surficial stream flow.

iii. Fringe Areas

The fringe area is a zone of infrequent inundation that is created. In a dry pond, this is the area just below and slightly above the HWL. The influence of inundation is less pronounced in this area. Therefore, plants must be able to tolerate infrequent inundation. Consideration should be given to using the appropriate species of grasses and shrubs. In general, trees are to be planted above the HWL.

iv. Upland Areas

Upland areas are the landscaped areas above the HWL that surround the pond. Plantings in this area should provide a minimum of a 3 m wide buffer strip above the HWL. The selection of plants in this area should consider:

- Type of amenity
- Access restriction to steep areas or inlet/outlet locations
- Careful planning of deciduous trees to minimize plugging of catchbasins and inlets/outlets in the pond due to leaves.
- Minimization of maintenance (naturalized landscaping where possible)
- Topography and surface drainage
- Soil conditions

6.2.2.15 Grading/Slopes

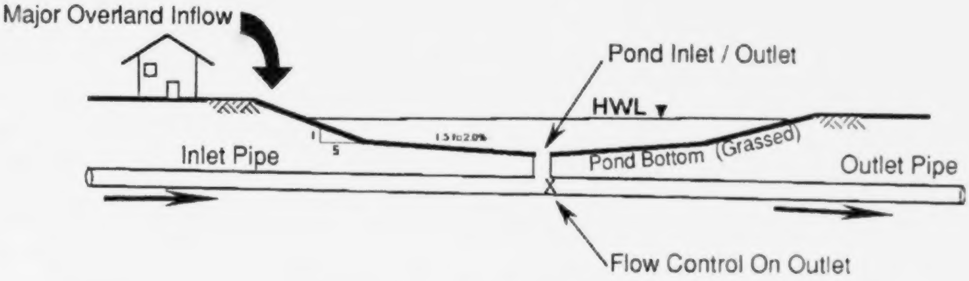


Figure 6.3: Dry Pond Slopes

i. Bottom Grading

The bottom of dry ponds shall be graded to properly drain all areas after operation. The minimum bottom slope is 1.5%. The recommended bottom slope is 2.0%.

ii. Side Slopes

The maximum side slope shall not exceed 5H:1V from pond bottom to high water level (HWL), including the freeboard.

Above the inundated area, side slopes no greater than 4H:1V are permitted for inward facing slopes. If the depth of the interior slope is significant, then stairs, or other means of exit, must be provided to ensure the safety of individuals, particularly children, exiting the pond.

Side slopes of 3H:1V maximum are permitted for outward facing slopes. This is the maximum slope permitted for mowing grass.

Relaxation of these slopes may be considered in localized areas subject to the approval of Wastewater & Drainage.

6.2.2.16 Subdrainage System

A subdrainage system (or weeping tile system) is required for all dry ponds, regardless of the elevation of the water table. The type of system installed should reflect the soil conditions at the location. Although there is no set standard for the subdrainage system, french drains or similar should be installed. The purpose of the subdrainage system is to improve drainage at the bottom of the pond so recreational fields (where permitted) are useable and maintenance (such as mowing or cleaning) can be performed. The depth of loam used in the dry pond must not adversely impact the function of the subdrainage system. All systems must be approved by Wastewater & Drainage.

6.2.2.17 Inlet(s), Inlet/Outlet(s) & Catchbasins

Depending on the design of the dry pond, there are generally three types of structures that permit the inflow of stormwater into the pond: inlet(s), inlet/outlet(s) and catchbasins. Inlet/outlet structures facilitate both inlet and outlet flow control and are often referred to as the outlet control structure (see following section).

i. The use of catchbasins (or drain inlets) in the bottom of the pond is encouraged. The drain inlets shall be 1.2 m diameter Type 5A barrels with the gratings bolted to the tops. Standard 0.9 m diameter catchbasins will be considered at the discretion of Wastewater & Drainage.

ii. The number of inlets into the pond should be kept to a minimum.

iii. Due to concerns for winter operation, the diameter of the inlet pipe should be 450 mm or larger. Inlet, inlet/outlet structures and catchbasins should be located to minimize exposure to blowing snow, and to maximize exposure to sunlight to reduce potential for ice buildup during freeze-thaw conditions.

iv. Erosion control measures should be provided at the bottom of the inlet/outlet structure(s). Erosion control should include interlocking stone or an approved concrete revetment system, either on the surface or subsurface.

v. Inlet velocities (through the gratings) should be limited to 1.5 m/s where possible to minimize erosion and scour, and re-suspension of sediments.

vi. Appropriate fencing and safety railings must be provided where the vertical depth ≥1 m. In general, it is preferable that the structure be landscaped into the slope.

Gratings

i. All inlet pipes and catchbasins shall have gratings provided over their openings to prevent access by children or unauthorized persons. The only exception is submerged inlets when there is a permanent pool. In this case, submerged inlets do not require gratings.

ii. All gratings shall be bolted. Bolting is to be recessed where possible. Inlet grates must have a minimum of 2 bolts per section; catchbasins must have a minimum of 2 bolts.

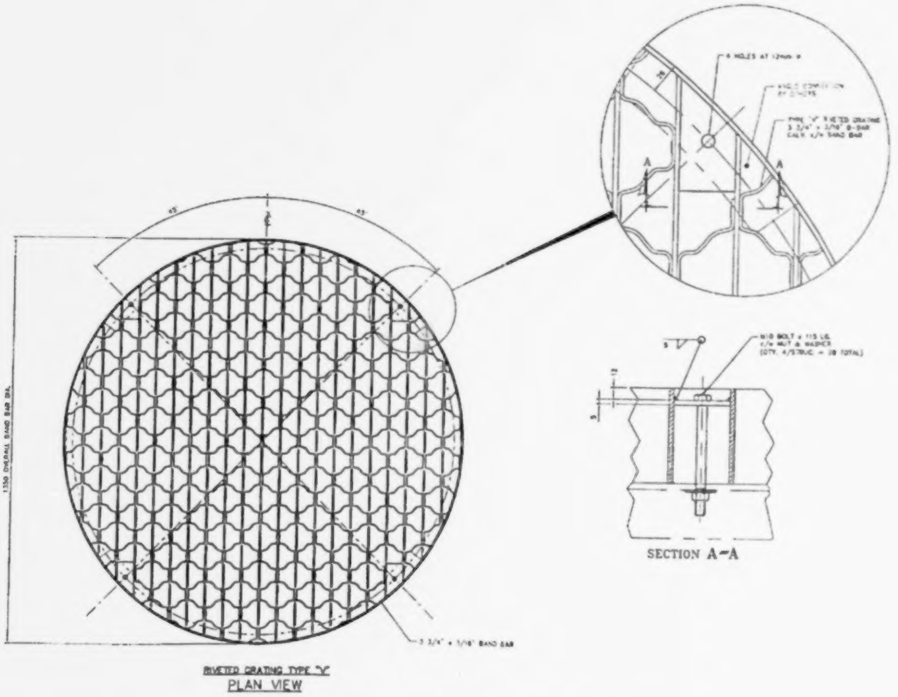


Figure 6.4: Typical CB Grating

iii. In general, Armtec Type V riveted grating (3-3/4" x 3/16" b-bar, galvanized) is to be used (see Figure 6.4). When flared end sections are used for inlets, the manufacturer's grating may be used. Any other grating type requires approval from Wastewater & Drainage.

iv. The velocity of the flow passing through the grating of the inlet/outlet structure should not exceed 1.5 m/s. Excessive velocities create a concern for children's safety during flooding and potential erosion.

v. All gratings shall be galvanized steel or approved equivalent. All gratings must also be coated with Armaguard (Armaguard Coatings-Calgary, AB) or an approved equivalent to provide a measure of safety for children.

vi. The size of a grating section on the inlet/outlet should not exceed 3m x 1m. Where larger gratings are required, more than one section should be used. The size of the gratings must be kept manageable to facilitate removal for maintenance purposes.

6.2.2.18 Outlet Control Structure

Typically, the outlet structure serves as the source of control for the release of stormwater from the pond. Consequently, the outlet structure is commonly referred to as the control structure or the outlet control structure. It is important that the structure be properly designed and constructed to provide minimal maintenance and enhance safety. Design of the control structure must be approved by Wastewater & Drainage. See **Sections 5.4** and **5.5** for additional design information.

Outlets typically consist of two chambers. A weir wall usually divides the two chambers. For maintenance access, the size of each chamber should be a minimum of 1.2m. However, the desired size is 1.8 m.

Orifice

The orifice provides the control for the permitted release rate for the pond. Typically, the orifice is located in the weir wall.

The recommended minimum orifice diameter is 50 mm. This is to minimize the possibility of clogging at the outlet. The preferred minimum diameter is 100 mm.

Where small orifices are required, consideration should be given to providing an overflow outlet that would operate in the event of blockage of the primary orifice.

The orifice plate should be constructed of galvanized steel or an approved equivalent.

Weir Wall

Dry ponds will typically have a weir wall in the control structure to provide a source of overflow for the pond in the event of a blockage of the orifice. The weir wall spill elevation should be set at the HWL elevation, or the calculated hydraulic grade line elevation.

Trash Rack

A trash rack must be installed to protect the orifice when the diameter is

≤ 200 mm. The trash rack must be galvanized and include an access to the orifice for maintenance purposes. The openings in the trash rack must large enough to prevent clogging on a frequent basis, yet small enough to provide protection to the orifice. Typically, an opening 25 to 50 mm smaller than the orifice diameter is suitable.

Gate Valve

All dry ponds require a gate valve. The gate valve is used as a bypass for the orifice in the event the orifice plugs, and for maintenance purposes. Although there is no set size specified, a minimum gate size of 300 mm diameter should be targeted where possible. Consideration should be given to not exceeding the design flow in the downstream storm pipe, except in emergency situations.

All gates should have non-rising stems that are operated mechanically, or manually with a T wrench. The T wrench should be located on the downstream end of the control structure in an easily accessible location.

The use of automatic control gate systems is not advocated. Wastewater & Drainage will review these designs on a site-specific basis only. An Operating and Maintenance manual is required for all automatic control gate systems.

Hydraulics

The hydraulic performance of the control structure is important to its operation. Hydraulic calculations should be provided where possible. Refer to **Section 5.0 Hydraulic Design**.

6.2.2.19 Maintenance Vehicle Access

i. Maintenance vehicle access from an adjacent street or lane must be provided to the control (or outlet) structure, and to the inlet structure(s) (if possible) of the pond.

ii. The vehicle access route must be a minimum of 3.0 m wide, but preferably 4.0 m wide. The surface must be driveable.

iii. Sharp turns are to be avoided; the minimum turning radius is 8 m.

iv. Suitable surfacing material is to be used (ie. pavement, gravel, etc.) The subgrade for the access route must be able to withstand a 13 tonne vacuum truck. The subgrade must conform to "Standard Specifications Streets Construction" by Streets (latest edition). Alternatives will be considered subject to approval by Wastewater & Drainage.

6.2.2.20 Fencing

In general, full perimeter fencing is not desired, unless required by Park Development & Operations or other business units. Most ponds provide recreational amenities that must be accessible to the public. Alternatives such as the strategic planting of vegetation to provide effective barriers are advocated. However, some facilities may be more susceptible to damage caused by prohibited vehicles. In these situations, sections of the pond may be protected by post and cable fencing, gates, bollards, or other approved alternatives.

Safety railings should be confined to critical areas where safety is a concern. This includes areas where the vertical drop is ≥ 1 m. Chain link fence is less desirable than safety railings and is only acceptable when the attached fencing does not protrude above the top rail.

Any required fencing must be in accordance with "Development Guidelines and Standard Specifications-Landscape Construction (latest issue) by Calgary Parks & Recreation.

6.2.2.21 Monitoring System

Remote water level monitoring equipment is required at all dry ponds to allow monitoring by Wastewater & Drainage staff (Systems Maintenance and Design) when the pond is being used for storage. The equipment shall be installed at the developer's expense. See **Section 6.1.9** and **Appendix C** for details.

6.2.2.22 Signage

All ponds are required to have appropriate signage. Signage is required at all entrances to the pond and at any other critical points. Locations should be identified on the Site/Overall pond drawing. See **Appendix D** for sign requirements. The developer is responsible for the cost of purchasing and installation. Arrangements can be made with Wastewater & Drainage (Systems Maintenance) to order and/or install the signs.

Signs promoting public education are encouraged. Signs may include information regarding operation and purpose of the pond, protection of the environment, water conservation, native landscaping, impact of chemicals and interpretative trails. Contact Wastewater & Drainage and/or Park Development & Operations for more information.

6.2.2.23 Enhancements

In general, Wastewater & Drainage will not fund any enhancements outside of the design specified above. Contact Wastewater & Drainage for more information.

6.3 Wet Ponds

6.3.1 Introduction

Wet ponds are impoundment areas used to temporarily store stormwater runoff in order to promote settlement of runoff pollutants, and to restrict downstream discharge to predetermined levels, to reduce downstream flooding and erosion potential. Wet ponds are similar to lakes in that there is always a permanent body of water. During rainfall events, additional temporary storage is provided above the permanent level. After the rainstorm, the water level gradually recedes back to its original level.

Wet ponds may be constructed by an embankment or through excavation of a depression. Design of the facility usually includes the upper stage (above PWL or NWL), where the volume from storm events is stored, and the lower stage (below NWL), where sedimentation is promoted. It is the lower stage that provides the pond's primary source of water quality enhancement. Sediment forebays are required on all wet ponds to help confine settlement for larger pollutant particles.

Wet ponds are a reliable end-of-pipe BMP. As well, they are normally less land-intensive than wetlands and are reliable in operation. Wet ponds have a moderate to high capacity to remove urban pollutants, and establishment of vegetative zones around the pond can enhance pollutant removal efficiency. Therefore, wet ponds can be used to provide both water quantity and water quality. However, good design of a wet pond involves attention to a variety of criteria.

6.3.2 Design

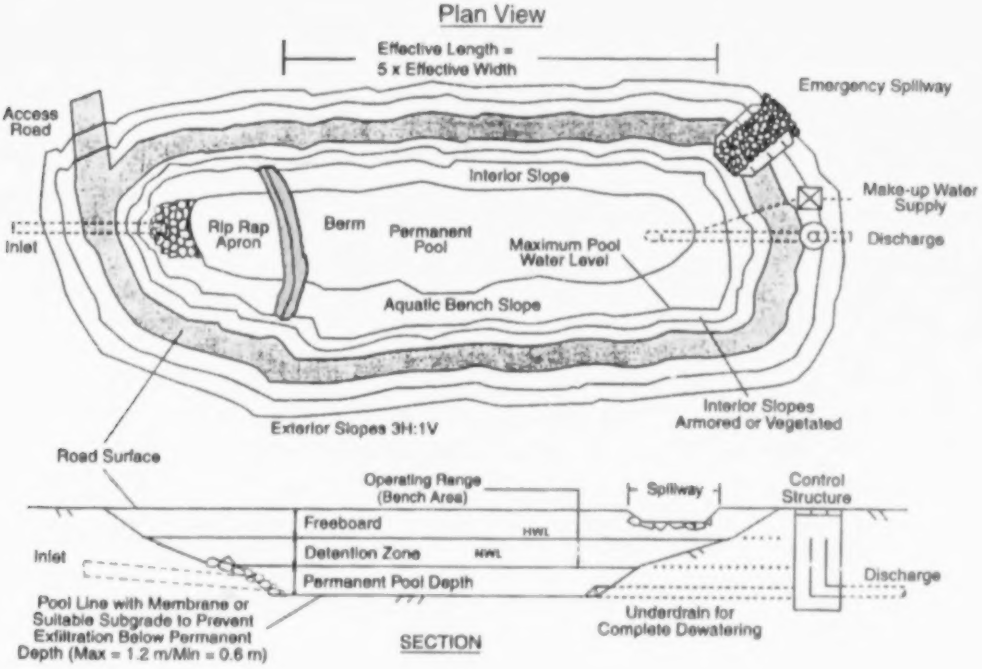

Plan View
Effective Length = 5 x Effective Width
Emergency Spillway
Access Road
Interior Slope
Make-up Water Supply
Inlet
Rip Rap Apron
Berm
Permanent Pool
Maximum Pool Water Level
Discharge
Aquatic Bench Slope
Interior Slopes Armored or Vegetated
Exterior Slopes 3H:1V
Road Surface
Operating Range (Bench Area)
Spillway
Control Structure
Freeboard
HWL
Inlet
Detention Zone
NWL
Permanent Pool Depth
Discharge
Pool Line with Membrane or Suitable Subgrade to Prevent Exfiltration Below Permanent Depth (Max = 1.2 m/Min = 0.6 m)
Underdrain for Complete Dewatering
SECTION

Figure 6.5: Wet Pond

Table 6.2: Design Summary Guide for Wet Ponds

Design Element	Design Objective	Minimum Criteria	Recommended Criteria
Level of Service/ Volumetric Sizing	Provision of appropriate level of protection and adequate volume for quantity and quality	100 year design and 80% removal of TSS for water quality Minimum quality volumes: Btm to NWL- 25mm x catchment area NWL to HWL- 25mm x catchment area	
Land Dedication	Appropriate location	PUL, ER	PUL
Drainage Area	Function of permitted release rate. Maintain minimum orifice size, limit number of ponds, maximum pond volume	Not applicable	Not applicable
Pond Area/ Number of Ponds	Maximum pond area, Limit number of ponds	2 ha at NWL	
Circulation	Prevent stagnation	Turnover rate of 2 times/year	
Water Quality	Pre-treatment	80% removal of TSS Min. 25mm x catchment area for permanent and active storage	

Design Element	Design Objective	Minimum Criteria	Recommended Criteria
Sediment Forebay	Pre-treatment (sedimentation)	Max area ≤ 1/3 permanent pool surface area Depth: 1.5 m Min. Appropriate Length and Width according to Section 6.3.2.8	2.0 m
Forebay Length:Width Ratio	Maximize flow path and minimize short-circuiting	Min. 2:1 measured along flow path	
Active Storage Detention Time	Suspended Solids Settling	24 hours	
Length:Width Ratio	Maximize flow path and minimize short-circuiting	Min. 3:1	4:1 to 5:1
Pond Depth	Safety, Control of weed growth	Btm to NWL: 2 m Min. 3 m Max. NWL to HWL: 2 m Max. Freeboard: 0.15m Min.	2.5 m
Overland Routes	Safety	Meets Alberta Environment Depth-Velocity guidelines	
Escape Route	Safety	Min. 1 to 2 m^3/s	Maximum possible
HGL	To prevent backup	No surcharging to surface	HGL impact confined to pipe adjacent to pond
Landscaping	Public Amenity & Safety	Approval of Wastewater & Drainage and Park Development & Operations Edge treatment required	
Recreational Activities	Public Safety	See List in Section 6.3.2.17	
Side Slopes	Drainage and Safety	Above HWL: 4H:1V to 5H:1V Max. Outward facing: 3H:1V Max. NWL to HWL: 5H:1V Max. Below NWL: - 2 m wide band 3H:1V - Remainder 5H:1V to 7H:1V Benches: 150mm to 300mm drop	
Geotechnical	Infiltration	Max: 1 x 10^{-6} cm/s	
Inlet	Safety & Maintenance	Crown: 0.8 m below NWL Invert: 100 mm above btm Skimmer MH req'd	
Outlet	Safety & Maintenance	1.2 m x 1.2 m/chamber	1.8 m x 1.8 m/chamber
Orifice	Avoid Plugging	50 mm diameter	100 mm diameter
Trash Rack (Exposed Outlet)	Protect Orifice from plugging	Req'd when orifice ≤ 200 mm diameter	
Gate Valve	Bypass & Maintenance	Required (300 mm diameter)	
Maintenance Vehicle Access	Access for equipment	Width: 3.0 m Turning Radius: 8 m	4.0 m
Fencing	Safety	Not generally required	
Monitoring Equipment	Safety & Design	Required (see Section 6.1.9 and Appendix C)	
Signage	Safety	Required (see Appendix D)	

Note: Refer to detailed information provided in following sections

6.3.2.1 Level of Service/Volumetric Sizing

Wet ponds must provide an active storage volume for a 100 year return period storm. However, the pond must also be sized to provide a minimum 80% removal of Total Suspended Solids (TSS) for particle sizes ≥75µm for water quality. The more conservative volume of the two criteria shall dominate. Refer to **Section 3.0 Stormwater Design** for more information.

There are two **minimum** water quality sizing criteria that must be met:

- As a minimum, the permanent pool (pond bottom to NWL) must be sized for a volume equal to 25 mm over the entire contributing drainage area (25 mm x catchment area).
- As a minimum, active storage (NWL to HWL) must be sized for a volume equal to 25 mm over the entire contributing drainage area (25 mm x catchment area). A minimum detention time of 24 hours must also be provided. The 100 year volume must be contained before spillover is permitted.

Release rates from the ponds must conform to the rates set out in the approved Master Drainage Plan report and/or approved Staged Master Drainage Plan report.

6.3.2.2 Land Dedication

Refer to "Calgary Open Space Plan" by Calgary Parks & Recreation (February 2000) for further information.

i. Wet ponds that are to be ultimately operated by The City of Calgary are to be located on Public Utility Lots (PUL).

ii. The use of MR and MSR lands for wet ponds will not be supported. Land located adjacent to public utility lands may be designated MR if the design of the pond provides a pathway or visual amenity.

iii. Use of ER may be supported if the wet pond can function as part of the natural drainage system and can be appropriately designed and managed. Approval from Park Development & Operations is required.

iv. Retrofit wet ponds may be supported in Major Natural Area Parks when there is minimal disturbance to the natural system. Approval from Park Development & Operations is required.

v. Wet ponds should not be located in river valleys unless there are no other viable locations.

vi. Where a wet pond is located on privately owned land, an easement is required to permit encroachment of water onto the property and restrict development in the areas subject to inundation. For ponds proposed on provincial lands, approval is required from the Province of Alberta. Contact Alberta Environment for more information.

vii. A maintenance agreement is required for any **public (City owned)** wet pond that will be operated and maintained by a private owner. Contact Wastewater & Drainage for further information.

viii. The maximum level of inundation, the high water level (HWL), must not encroach onto private property. Lots bordering the wet pond are required to have abutting property elevations a minimum of 0.3 m above the spillover elevation of the pond.

6.3.2.3 Drainage Area

There currently is no minimum drainage area requirement. The contributing drainage area requirement for a wet pond is a function of the permitted release rate and water quality requirements.

6.3.2.4 Pond Area & Number of Ponds

The minimum area of a wet pond shall be 2 ha at the normal water level (NWL). Smaller areas will only be considered on a site-specific basis at the discretion of Wastewater & Drainage. In such cases, the private owner may be required to enter into a private maintenance agreement.

From a maintenance perspective, economies of scale can be realized with fewer and larger wet ponds. The developer shall make every effort throughout the planning process to limit the number of ponds required.

6.3.2.5 Winter Operation

During the winter, ice cover will reduce the design volume of the permanent pool. While there are currently no requirements to compensate for the loss of volume due to ice cover, precautions should be taken to minimize the effects of freezing of pipes and orifices.

6.3.2.6 Circulation

Narrow and/or dead bay areas are not permitted. Inlets and outlets should be located to maximize detention time and circulation, and to reduce short-circuiting through the pond.

A minimum turnover rate of the permanent pool volume is required twice per year based on Calgary's average annual precipitation.

6.3.2.7 Water Quality

All wet ponds are required to provide enhanced water quality. Wet ponds are to be sized to provide a minimum 80% removal of Total Suspended Solids (TSS) for particle sizes ≥75μm. For more information on particle size and settling velocities for modelling purposes, refer to **Section 7.5.3.2**.

As a **minimum**, the permanent pool (pond bottom to NWL) must be sized for a volume equal to 25 mm over the entire contributing drainage area (25 mm x catchment area). As well, the active storage (NWL to HWL) must be sized for a **minimum** volume equal to 25 mm over the entire contributing drainage area (25 mm x catchment area). A minimum detention time of 24 hours must also be provided. The 100 year volume must be contained before spillover is permitted.

Water quality monitoring is also required during the maintenance period (See **Section 7.8**). Contact the Water Quality Engineer (Wastewater & Drainage) for more information. Costs of the program are to be covered by the developer during the maintenance period.

6.3.2.8 Sediment Forebay

A sediment forebay facilitates maintenance and improves pollutant removal of larger particles near the inlet of the pond. The forebay should be one of the deeper areas of the pond to minimize the potential for particle re-suspension.

Sediment forebays are required on all wet ponds. The forebay can be included within the wet pond area or as a separate facility. As well, each inlet location must have a forebay.

Sizing

Sizing of the forebay depends on the inlet configuration. There are several calculations that need to be made to ensure that it is adequately sized.

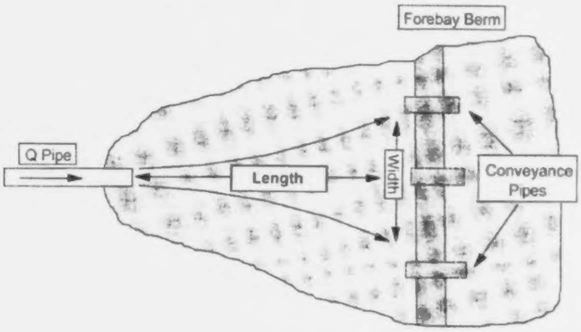


Figure 6.6: Forebay for Wet Pond

i. Settling Calculations

"The primary method to calculate forebay volume and length should be based on settling calculations. The calculations determine the distance required to settle out a certain size of sediment (see Table 7.2). It is assumed that the flow out of the pond dictates the velocity through the forebay and the rest of the pond. Although this is not entirely correct, it is reasonable for the determination of an appropriate forebay length."

Equation 6.1 defines the appropriate forebay length for a given settling velocity and hence particle size to be trapped in the forebay.[2]

$$\text{Length} = [rQ_p/V_s]^{0.5} \qquad \textbf{Equation 6.1 (Forebay Settling Length)}$$

where Length= forebay length (m)
r = length to width ratio of forebay
Q_p = peak flow rate from the pond during the design storm (m^3/s)
V_s = settling velocity (dependent on the desired particle size to settle). A value of 0.0003 m/s may be used in most cases.

The forebay area should not exceed one third of the total permanent pond surface area. As well, the length to width ratio in the forebay should be $\geq$ 2:1.

---

[2] Ontario Ministry of the Environment, "*Stormwater Management Planning and Design Manual-DRAFT FINAL*", 1999

ii. Dispersion Length

"The dispersion length refers to the length of fluid required to slow a jet discharge, such as pipe flow. A check can be made on the forebay length given by the settling calculation (Equation 6.1) to ensure that there is adequate dispersion. Equation 6.2 provides a simple guideline for the length of dispersion required to dissipate flows from the inlet pipe. It is recommended that the forebay length is such that a fluid jet will disperse to a velocity of ≤ 0.5 m/s (discharge jet) at the forebay berm."[3]

A check of the entire forebay cross-sectional area should ensure that the average velocity in the forebay is ≤ 0.15 m/s. This velocity (0.15 m/s) is the maximum permissible velocity before which erosion will occur in a channel.

Typically, the dispersion length is smaller than the settling length unless there is a large upstream drainage area or the pond is subject to large inflows. When this occurs, the pipe design capacity should be used. **In all cases, the forebay length (designated Length) should be greater than, or equal to, the larger of the two forebay lengths given by equations 6.1 and 6.2.**

$$\mathbf{Length = (8Q)/(dV_f)}$$ **Equation 6.2** **(Dispersion Length)**

where
Length= length of dispersion (m)
Q = inlet flow rate (m^3/s)
d = depth of the permanent pool in the forebay (m)
V_f = desired velocity in the forebay (m/s). A value ≤ 0.5 m/s should be used.

The depth of the permanent pool in the forebay, d, reflects the deep section of the forebay required to minimize re-suspension and scour.

iii. Width

The minimum bottom width of the deep zone in the forebay is given by:

$$\mathbf{Width_{bottom} = Length/8}$$ **Equation 6.3** **(Minimum Forebay Bottom Width)**

The bottom forebay width is calculated using the largest length derived from Equations 6.1 and 6.2.

---

[3] Ontario Ministry of the Environment, "*Stormwater Management Planning and Design Manual-DRAFT FINAL*", 1999

iv. Depth

The minimum depth of the sediment forebay should be 1.5 m. The recommended minimum depth is 2.0 m.

v. Length:Width Ratio

The total length of the forebay should provide a length to width ratio ≥ 2:1 for each inlet. A length to width ratio < 2:1 is undesirable since the storage will not be utilized effectively. In this case, the addition of flow baffles, or other means of lengthening the flow path in the forebay, may be used, subject to approval by Wastewater & Drainage. When lengthening methods are used, effective length is measured along the flow path.

6.3.2.9 Forebay Berm

An earthen berm should be used to separate the forebay from the rest of the pond. The top of the berm should be submerged slightly, 0.15 m to 0.3 m below the normal water level (NWL). A submerged berm provides a safety benefit to the public (provides a barrier to the public walking along the berm) and allows vegetation to be planted around and along the berm. The berm should be constructed with a solid substrate to facilitate removal of accumulated sediment and debris.

Emergent vegetation should be planted along the berm to promote filtration of water as it passes over (see **Appendix E** for species). The plants should be established on the top and sides of the berm at a maximum planting depth of 30 cm.

Although not required, pipes may be installed in the berm to serve as the primary conveyance system from the forebay to the pond, or as a secondary conveyance system to supplement flows over the submerged berm. Flow calculations should be made to ensure the berm does not create a flow restriction, causing the forebay to overflow under design conditions.

The invert of any conveyance pipes installed in the berm should be set at least 0.6 m above the bottom of the forebay to prevent siphoning of settled material into the rest of the pond. A maintenance pipe/valve should also be installed in the berm to allow drawdown of the forebay during maintenance. If only the forebay is to be pumped out or drawn down during maintenance, the forebay berm must be designed as a small dam since the rest of the pond will not be drained. Care must be taken not to compromise the structural integrity of the berm or liner during drawdown conditions.

6.3.2.10 Detention Time

A minimum detention time of 24 hours is required to promote water quality enhancement for active storage. Detention time is defined as the theoretical time required to displace the contents of a stormwater pond at a given rate of discharge (ie. volume divided by rate of discharge).

6.3.2.11 Length:Width Ratio

The overall performance of the pond is influenced by the flow path through the pond. Problems encountered with earlier pond designs include construction of the outlet too close to the inlet, and having multiple inlets at opposing ends of the pond based on servicing convenience. In both cases, short-circuiting reduces the effective volume of the facility.

Where possible, all stormwater servicing should be conveyed to one inlet location. To provide the longest flow path though the pond, the inlet should be located as far away from the outlet as possible. A pond with a minimum length to width ratio of ≥ 3:1 will generally have an acceptable flow path. The preferred length to width ratio ranges from 4:1 to 5:1. A ratio outside of this range requires the approval of Wastewater & Drainage. Effective length excludes forebay length.

The provision of additional berms or flow baffles in the pond to redirect flows and lengthen the flow path is also acceptable to ensure short-circuiting will not occur.

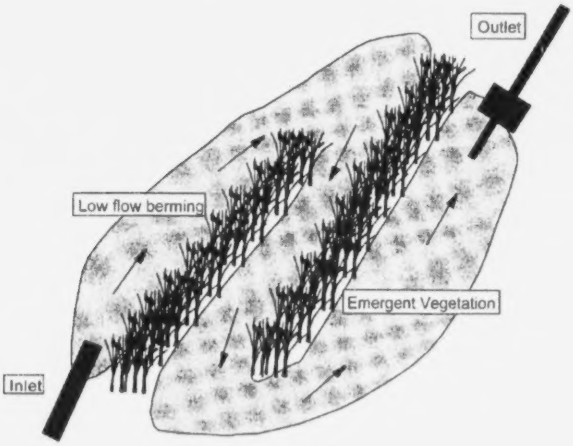


Figure 6.7: Extending the Flow Path

6.3.2.12 Pond Depth

The depths of the permanent and active storage areas are based on a variety of criteria, including potential stratification, the tolerance of plants to fluctuating water levels, and safety.

Permanent Storage Area

The **minimum** depth from the pond bottom to NWL shall be 2 m, with the recommended depth being 2.5 m. A depth of 2.5 m minimizes aquatic growth in the pond and maximizes recreational potential.

A **maximum** depth of 3 m should not be exceeded. Depths in excess of 3 m require approval from Wastewater & Drainage. Although ponds deeper than 3 m may have benefits in terms of temperature, stratification is more likely, resulting in anoxic conditions which release metals and organics from the pond sediments.

Active Storage Area

The **maximum** active storage depth shall be 2 m. Depths in excess of 2 m require approval from Wastewater & Drainage. The active storage depth is defined as the depth between NWL and HWL. In addition, a minimum freeboard of 0.15 m is required above HWL.

6.3.2.13 Overland Drainage Routes

i. Overland drainage routes that direct flows from the 100 year storm event to the pond area shall be provided. Overland flow design velocities (v) and depths (d) must be in accordance with "Stormwater Management Guidelines" for the Province of Alberta (January 1999). See **Table 3.15 and Figure 3.9**. Erosion control needs must be evaluated.

ii. An emergency overland escape route from all ponds is to be provided. In general, the escape route must provide a minimum capacity between 1 and 2 m^3/s. Appropriate capacity should be determined at the time of design.

Optionally, additional freeboard may be considered in cases where it is difficult to establish an escape route. The additional freeboard would provide a higher level of service overall.

iii. Sanitary sewer manholes must be located outside of impoundment (pond) areas. Whenever possible, sanitary sewer manholes should not be located within the overland drainage route.

iv. Sanitary sewer manholes located within overland drainage routes must be sealed. Bolting is at the discretion of Wastewater & Drainage.

6.3.2.14 Hydraulics

The 100 year elevation will be established taking into consideration the adjacent footing elevations. When the wet pond is at the 100 year elevation, water should not back up through the storm sewer and weeping tile connections to create hydraulic pressure on foundations. Areas affected by the HWL and resulting hydraulic grade line should be kept to a minimum. Free flow conditions are preferable; this is achieved when the crown of the closest incoming storm sewer(s) is at or above the HWL. All hydraulic conditions must be approved by Wastewater & Drainage. Refer to **Section 5.0 Hydraulic Design** for more information.

When free flow conditions are not achieved based on the HWL, hydraulic grade line (HGL) elevations in the storm sewers must be determined based on the pond at HWL and the appropriate losses taken into account (ie. junction losses, pipe losses, etc.). **Surrounding footing (or slab) elevations must be a minimum of 0.3 m above the HGL.** Other options to protecting weeping tile connections include a separate weeping tile system connected downstream of the pond, or sump pump to surface. Weeping tile connected to sanitary is not permitted in any circumstances.

Surcharging to ground surface will **not** be permitted. Contact Wastewater & Drainage for further information.

Backflow prevention devices are required on all weeping tile connections as per the Alberta Plumbing Code.

All upstream storm piping below the HWL and HGL must be rubber gasketed.

6.3.2.15 Landscaping & Vegetation

Landscaping and vegetation plans must be submitted with the construction drawings. The drawings must be reviewed and approved by Wastewater & Drainage and Park Development & Operations. All landscaping must be prepared by a qualified consultant and must conform to "Development Guidelines and Standard Specifications-

Landscape Construction" (latest issue) by Calgary Parks & Recreation. Refer to **Appendix E for Recommended Plant Species**.

A planting strategy is required to provide shading, aesthetics, safety, enhanced pollutant removal and waterfowl control. The purpose of the planting is to provide a sustainable community with a **naturalized treatment**. Plants native to Calgary should be used where possible. Planting density may not have to be high, as natural succession will ultimately make up the vegetation. As well, the overall planting should be designed to minimize maintenance. Manicured and mown areas should be kept to a minimum, as these areas can attract waterfowl and become a problem.

For a list of plant species, refer to **Appendix E**.

i. Deep Water Areas

The majority of area in a wet pond is comprised of deep water areas. Plantings in deep water areas are restricted to submergent vegetation. Pondweeds and other species can be planted in appropriate water depths. Refer to **Appendix E**. The transition between shallow and deep water plantings will eventually establish itself according to water level fluctuations and light availability.

ii. Shallow Water Areas

Shallow water areas are considered to be the areas of the permanent pool where the depth is ≤ 0.5 m. This is usually defined as the perimeter of the pond.

The selection of vegetation should consider nutrient uptake, stormwater filtration, safety, and aesthetics. Other benefits include the prevention of re-suspension of bottom sediments and the reduction of flow velocities to aid in sedimentation.

Plant species in this zone includes both submergent and emergent vegetation (see **Appendix E**). Submerged plant species should be planted in water depths between 0.3 m and 0.5 m. Emergent plant species should be planted at water depths starting at 0.3 m. The side slopes will determine the amount of vegetation that can be established.

iii. Fringe Areas

Shoreline Fringe Areas

Shoreline fringe areas are the areas subject to frequent wetting from storm events. In general, this is the land delineated between the NWL and HWL for erosion/water quality control. This area will typically have higher soil moisture conditions during the frequent storm events. The area close to the NWL elevation is subject to more frequent flooding and wave action from the pond. This area must be adequately protected from erosion.

The planting strategy for this area should be similar to the shallow marsh area. Plant species should include hardy hydric grasses and shrubs (see **Appendix E**). Due to the frequency of inundation, plant stocks should be used instead of seeds.

Floodfringe Areas

When the wet pond is used to control peak flow rates, a zone of infrequent inundation is created. This zone is referred to as the floodfringe area and is generally the area just below and slightly above the HWL. Plant species in this zone should include a range of grass, herb and shrub species. In general, trees are to be planted above the HWL. (see **Appendix E**)

In addition, thorny or dense vegetation may be planted to provide safety measures, as an alternative to fencing. Together with other plantings, an effective barrier to public entry can be created.

iv. Upland Areas

Upland areas are the landscaped areas above the HWL that provide aesthetic amenities around the pond. Plant species should be designed to restrict access to steep areas or inlet/outlet locations. See **Appendix E** for a list of plant species. A naturalized landscape should be designed to consider:

- topography and drainage
- soil conditions
- adjacent plant communities
- availability of nursery stocks
- potential for on-site transplantation
- minimal maintenance

A minimum horizontal buffer strip of 3 m should be provided between the HWL and the property line, or a 10 m horizontal buffer strip between NWL and the property line, whichever is greater.

Any pathways to be incorporated must be constructed above the 100 year elevation (HWL). Pathway locations and design should also have regard for protection of any native habitats created or protected. Any deviations require the approval of Wastewater & Drainage and Park Development & Operations.

6.3.2.16 Pond Edge Treatment

Edge treatment or shore protection is required. The area close to the NWL elevation is subject to more frequent flooding and wave action from the pond. This area must be adequately protected from erosion. Treatment must be compatible with the adjacent land use and shall provide for low maintenance and safety.

The edge treatment must cover the ground surfaces a horizontal distance of 1.5 m below NWL and 3.0 m above NWL. The treatment must be adequate to prevent erosion of the edge due to wave action.

Although typical treatment in the past has been for granular material on top of filter fabric, the designer is encouraged to propose alternate edge treatments that exceed this standard and provide an overall "softening" effect.

6.3.2.17 Recreational Activities

Stormwater wet ponds can add recreational and environmental features to an urban area. Although wet ponds can provide potential recreational benefits, there are potential risks associated with these activities.

Contact with stormwater in a wet pond can cause skin irritation (swimmer's itch) and ingestion can make people ill. Since the water quality in a wet pond does not generally meet the Alberta Environmental Protection Act (EPA) Guidelines, activities that involve direct water contact are prohibited.

Prohibited activities include swimming and wading. Also prohibited is use of motorized boats since this activity is a potential source of noise, nuisance, and petroleum product spills. The exception is the use of motorized boats for emergency or maintenance purposes.

Activities that are **permitted** are categorized as secondary and tertiary activities. These include:

Secondary Activities

- Canoeing
- Kayaking
- Paddle boating

- Rafting
- Model boating

Tertiary Activities

- Photography
- Bird watching
- Bicycle riding
- Jogging
- Walking
- Tobogganing
- Outdoor picnicking
- Arts and crafts

Ice related activities, such as skating and cross-country skiing, are not supported since the ponds are not monitored for ice thickness. Tobogganing activities should be confined to safe areas. For further information, contact Wastewater & Drainage.

6.3.2.18 Grading/Slopes

Grading and landscaping of the pond and adjacent areas is important for public safety and functionality of the pond.

Side Slopes

i. Typical side slope requirements are shown in Figure 6.8.

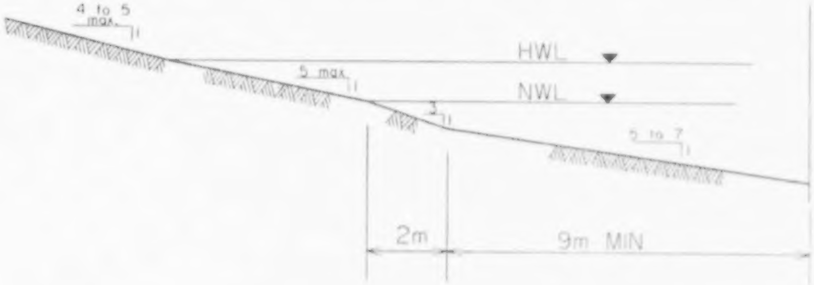


Figure 6.8: Side Slopes for Wet Ponds

ii. Grading above the HWL shall be 4H:1V to 5H:1V maximum. For outward facing slopes, grading shall not exceed 3H:1V.

iii. Grading between NWL and HWL shall be 5H:1V maximum.

iv. Below NWL, a 3H:1V slope is required for a horizontal distance of 2 m. This is to discourage weed growth and discourage public access.

v. The remainder of slope below NWL is to be 7H:1V to 5H:1V maximum.

vi. Alternative side slope designs will be considered. This includes aquatic benches to enhance vegetation and naturalization. Small drops of 150 mm to 300 mm can be incorporated to serve as a warning to public accessing deeper water. Contact Wastewater & Drainage for approval.

6.3.2.19 Geotechnical

A geotechnical report must be undertaken by a qualified geotechnical consultant that addresses issues related to the design of the wet pond. The purpose of the report is to determine criteria such as dam safety (as required), underdrainage design (ie. toe drains), liner requirements (infiltration), and any other special design conditions such as slope stability. See **Section 6.1.6**.

Pond bottom material is to be composed of impervious material with a suitable low permeability (permeability coefficient in the order of 1×10^{-6} cm/s). Preference should be given to using clay where possible or an acceptable alternative; puncturing of liner materials during sediment removal is a concern. Organic soils are not permitted.

The report must be submitted and approved by Wastewater & Drainage prior to submission of the construction drawings. The geotechnical report should be submitted with the Stormwater Pond report, the Master Drainage Plan report, or the Staged Master Drainage Plan report, whichever is the most practicable. Required details must be indicated on the construction drawings.

Geotechnical reports shall be submitted to Alberta Environment, Municipal Approvals, at the pre-design stage for stormwater ponds that may be classified as a dam (see **Section 2.3.3.1**); approval under the Water Act is required. Drawings of the pond shall also be submitted. Municipal Approvals will forward the information to the Dam Safety and Water Projects Branch as part of the review process. Contact Alberta Environment, Municipal Approvals for more information.

6.3.2.20 Inlet(s)

Depending on the design of the wet pond, an inlet is generally the only type of structure that permits the inflow of stormwater into the pond. In order to provide water quality treatment, the flow must go through the wet pond to the opposite end.

i. Inlets should **not** be located close to the outlet control structure to minimize short circuiting.

ii. Ideally there should only be one discharge location, or inlet, into the wet pond. Multiple inlets should be avoided where possible.

iii. All inlets and outlets are to be fully submerged with the crown of the pipe a minimum of 0.8 m below NWL. Partially submerged inlets are not permitted due to concerns with ice formation.

iv. Inlet and outlet pipe inverts are to be a minimum of 100 mm above the pond bottom; depths in excess of 100 mm are recommended to prevent sedimentation from blocking the inlet pipe. Erosion control measures must be provided at the bottom of the inlet structure(s) to control erosion and scour. Erosion control measures should include the installation of a hard-bottomed surface, interlocking stone, or an approved concrete revetment/armouring system near the inlet pipe. Other enhancements such as dissipators or deflection structures will help minimize scour and re-suspension.

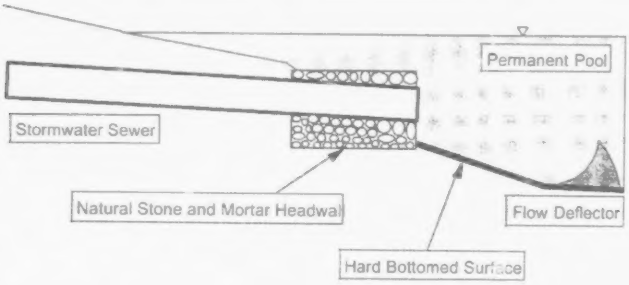


Figure 6.9: Submerged Inlet

v. Inlet velocities should be limited to 1.5 m/s where possible to minimize erosion and scour, and re-suspension of sediments.

vi. The invert elevation of the inlet pipe(s) to the first manhole upstream from the wet pond shall be at or above the normal water level (NWL) of the pond to avoid deposition of sediments in the inlet and freezing problems.

vii. A skimming type manhole or approved equivalent must be constructed on the first manhole upstream of the inlet(s). The purpose of the skimming manhole is to collect floatables (hydrocarbons, paint, etc.) and debris prior to entering the pond.

viii. Gratings are not required on submerged inlets.

6.3.2.21 Outlet Control Structure

Typically, the outlet control structure serves as the source of control for the release of stormwater from the pond and the preservation of the normal water level elevation. The outlet structure is commonly referred to as the control structure or the outlet control structure. It is important that the structure be properly designed and constructed to provide minimal maintenance and enhance safety. Design of the control structure must be approved by Wastewater & Drainage. See **Sections 5.4** and **5.5** for additional design information.

The control structure for a wet pond typically consists of three chambers. There are usually two weir walls, one to control the normal water level (NWL) and one to control the high water level (HWL). Other control structure designs may include two chambers. For maintenance purposes, the size of each chamber should be a minimum of 1.2 m. However, the desired size is 1.8 m.

Orifice

Usually an orifice provides the control for the permitted release rate for the pond. The recommended minimum orifice diameter is 50 mm. This is to minimize the occurrence of clogging at the outlet. The preferred minimum diameter is 100 mm.

Where small orifices are required, consideration should be given to providing an overflow outlet that would operate in the event of blockage of the primary orifice.

The orifice plate should be constructed of galvanized steel or an approved equivalent.

Weir Walls

Wet ponds will typically have two weir walls in the control structure: one to control the normal water level (NWL) and one to control the high water level (HWL) to provide a source of overflow for the pond in the event of a blockage of the orifice. The weir wall controlling the overflow should be set at the HWL elevation, or the calculated hydraulic grade line elevation.

Trash Rack

A trash rack may be required depending on the design of the outlet pipe and/or outlet control structure. A submerged outlet pipe and/or outlet control structure will not require a trash rack.

For an exposed outlet control structure, a trash rack must be installed to protect the orifice when the diameter is ≤ 200 mm. The trash rack must be galvanized and include an access to the orifice for maintenance purposes. The openings in the trash rack must large enough to prevent clogging on a frequent basis, yet small enough to provide protection to the orifice. Typically, an opening 25 to 50 mm smaller than the orifice diameter is suitable. Since the drainage area to a wet pond is usually large, the diameter of the orifice is normally large enough so that a trash rack is not required.

Gate Valves

All wet ponds require a gate valve. The gate valve is used as a bypass for the orifice in the event the orifice plugs, and for maintenance purposes. Although there is no set size specified, a minimum gate size of 300 mm diameter should be targeted where possible. Consideration should be given to not exceeding the design flow in the downstream storm pipe, except in emergency situations.

With the three chamber design, two bypass gate valves are required, one in the NWL weir wall and one in the HWL weir wall.

All gates should have non-rising stems that are operated mechanically, or manually with a T wrench. The T wrench should be located on the downstream end of the control structure in an easily accessible location.

The use of automatic control gate systems is not advocated. Wastewater & Drainage will review these designs on a site-specific basis only. An Operating and Maintenance manual is required for all automatic control gate systems.

Hydraulics

The hydraulic performance of the control structure is important to its operation. Hydraulic calculations should be provided where possible. Refer to **Section 5.0 Hydraulic Design**.

6.3.2.22 Maintenance Vehicle Access

i. Maintenance vehicle access from an adjacent street or lane must be provided to the control (or outlet) structure, and to the inlet structure(s) (if possible) of the pond. The sediment forebay must also be readily accessible for maintenance purposes.

ii. The vehicle access route must be a minimum of 3.0 m wide, but preferably 4.0 m wide. The surface must be driveable.

iii. Sharp turns are to be avoided; the minimum turning radius is 8 m.

iv. Suitable surfacing material is to be used (ie. pavement, gravel, etc.) The subgrade for the access route must be able to withstand a 13 tonne vacuum truck. The subgrade must conform to "Standard Specifications Streets Construction" by Streets (latest edition). Alternatives will be considered subject to approval by Wastewater & Drainage.

6.3.2.23 Fencing

In general, full perimeter fencing is not desired, unless required by Park Development & Operations or other business units. If there is a concern for safety due to the pond being in a remote location, fencing may be requested. Most ponds provide recreational amenities that must be accessible to the public. Alternatives such as the strategic planting of vegetation to provide effective barriers are advocated. However, some facilities may be more susceptible to damage caused by prohibited vehicles. In these situations, sections of the pond may be protected by post and cable fencing, gates, bollards, or other approved alternatives.

Safety railings should be confined to critical areas where safety is a concern. This includes areas where the vertical drop is ≥ 1 m. Chain link fence is less desirable than safety railings and is only acceptable when the attached fencing does not protrude above the top rail.

Any required fencing must be in accordance with "Development Guidelines and Standard Specifications-Landscape Construction (latest issue) by Calgary Parks & Recreation.

6.3.2.24 Monitoring System

Remote water level monitoring equipment is required at all wet ponds to allow level monitoring by Wastewater & Drainage staff (Systems Maintenance and Design) when the pond is being used for storage. The equipment shall be installed at the developer's expense. See **Section 6.1.9** and **Appendix C** for details.

6.3.2.25 Signage

All ponds are required to have appropriate signage. Signage is required at all entrances to the pond and at any other critical points. Locations should be identified on the Site/Overall pond drawing. See **Appendix D** for sign requirements. The developer is responsible for the cost of purchasing and installation. Arrangements can be made with Wastewater & Drainage (Systems Maintenance) to order and/or install the signs.

As well, an information sign (see **Appendix C**) is required at the most prominent entrance to the wet pond. The purpose of the sign is to inform people about the function of the wet pond, and to provide a contact number for further information or to report problems. It is the responsibility of the developer to supply and install the sign.

Signs promoting public education are encouraged. Signs may include information regarding operation and purpose of the pond, protection of the environment, water conservation, native landscaping, impact of chemicals and interpretative trails. Contact Wastewater & Drainage and/or Park Development & Operations for more information.

6.3.2.26 Public Education

It is the responsibility of the developer to provide an education brochure on wet ponds during the marketing of an area that includes a wet pond. The purpose of the brochure is to educate residents on:

- the specific function of wet ponds
- the water quality inherent with the function of the pond and the impact of water quality resulting from fertilizers (which indirectly feeds into the sewer system by surrounding residents)
- permitted recreational uses
- maintenance concerns and the potential for increased maintenance charges to residents to increase the level of maintenance deemed necessary

Wastewater & Drainage will undertake an annual distribution of a door hanger with the above information to communities with a wet pond. Distribution will start after construction of the pond.

6.3.2.27 Enhancements

In general, Wastewater & Drainage will not fund any enhancements outside of the design specified above. This includes water fountains, aerators, waterfalls, boat docks, etc. Contact Wastewater & Drainage for more information.

6.4 Wetlands

6.4.1 Introduction

"Conventional stormwater wetlands are shallow pools that create conditions suitable for the growth of marsh plants. These stormwater wetlands are designed to maximize pollutant removal through wetland uptake, retention and settling."[4] Stormwater wetlands are constructed systems that are designed to mitigate the impacts of stormwater quantity and quality.

Constructed stormwater wetlands are not typically located within natural wetland areas, which provide critical habitat and an ecosystem. As well, stormwater wetlands should not be used to mitigate the loss of natural wetlands. When stormwater becomes a major component of the water balance of a natural wetland, the functional and structural qualities of the wetland can be negatively altered. A natural wetland is a complex system that integrates water, plants, animals, microorganisms, and the environment. However, knowing how wetlands are structured and how they function will increase the likelihood of constructing a successful treatment wetland. It must be recognized that stormwater wetlands are first and foremost stormwater management facilities; they should never be considered as significant natural areas requiring environmental protection. Where a natural wetland is incorporated, protection of the wetland must be considered. The design criteria that follows is for constructed wetlands; a distinction needs to be made between natural and constructed wetlands.

Constructed stormwater wetlands can be created by an embankment or through excavation of a depression. The hydrology of a wetland is primarily one of slow flows and shallow water depth to allow the settling of sediments as the water passes through the wetland. Sedimentation, filtration, biological, and chemical processes account for the water quality benefits provided by the wetlands.

Stormwater wetlands are an end-of-pipe BMP. Although wetlands do provide water quality enhancement, the reliability for pollutant removal is similar to wet ponds (Schueler, 1992). There are also some drawbacks, which include a relatively high land area requirement, a need for intensive management after establishment, and the potential for adverse impacts within sensitive watersheds.

---

[4] Metropolitan Washington Council of Governments, "*A Current Assessment of Urban Best Management Practices-Techniques for Reducing Non-Point Source Pollution in the Coastal Zone*", 1992

Constructed wetlands are relatively new to Calgary. Limited operational and water quality monitoring data from wetlands in Calgary makes it difficult to determine the effectiveness of wetlands compared to wet ponds. Although wet ponds are encouraged over wetlands at this point in time, wetlands do have a place in stormwater management if well researched and designed properly. Wetlands do have the potential advantage of removing finer sediment particles than wet ponds, and in effectively treating nutrients, BOD and other pollutants. Due to the variability of design criteria, approval to construct a wetland is required from Wastewater & Drainage at the planning stage. Wetlands should not simply be constructed as a marketing feature to sell lots. A wetland provides a valuable ecosystem.

Stormwater wetlands fall into five basic designs: shallow marsh, pond-wetland, extended detention wetland, pocket wetland and fringe wetland. For additional information, see **Appendix F**.

i. Shallow Marsh System

A shallow marsh system has a large surface area and requires a reliable source of baseflow or groundwater to support emergent vegetation (see Figure 6.10). As a result, considerable area is required and a sizeable contributing drainage area to support the shallow permanent pool. A drainage area larger than 10 ha is generally required to support permanent water levels.

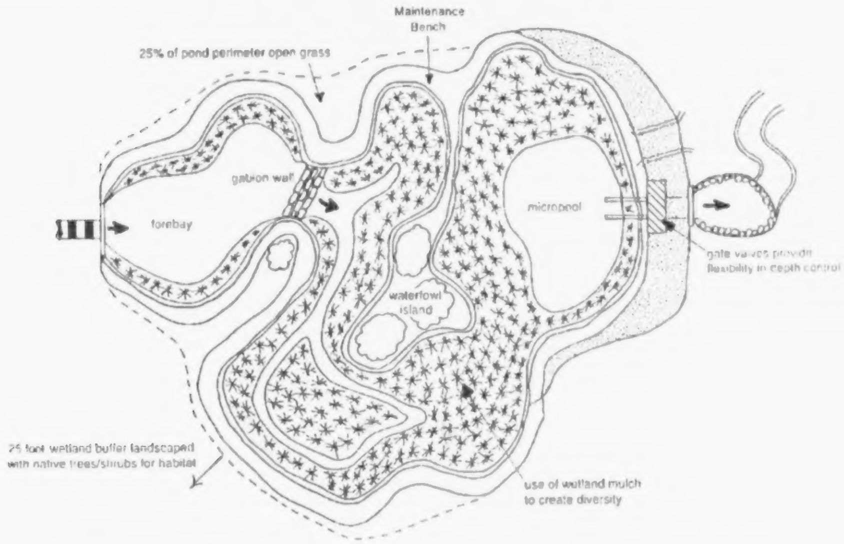

Maintenance Bench
25% of pond perimeter open grass
gabion wall
forebay
micropool
gate valves provide flexibility in depth control
waterfowl island
25 foot wetland buffer landscaped with native trees/shrubs for habitat
use of wetland mulch to create diversity

Figure 6.10: Shallow Marsh System (Schueler, 1992)

ii. Pond-Wetland System

The pond-wetland system design uses two separate cells for stormwater treatment (see Figure 6.11). The first cell is a wet pond and the second cell is a shallow marsh. The primary function of the wet pond is to trap sediments, reduce the velocity of the incoming runoff, and to remove pollutants. The pond-wetland system requires less area than the shallow marsh system since the majority of the treatment is provided by the wet pond rather than the shallow marsh. In this case, the wet pond acts as the sediment forebay.

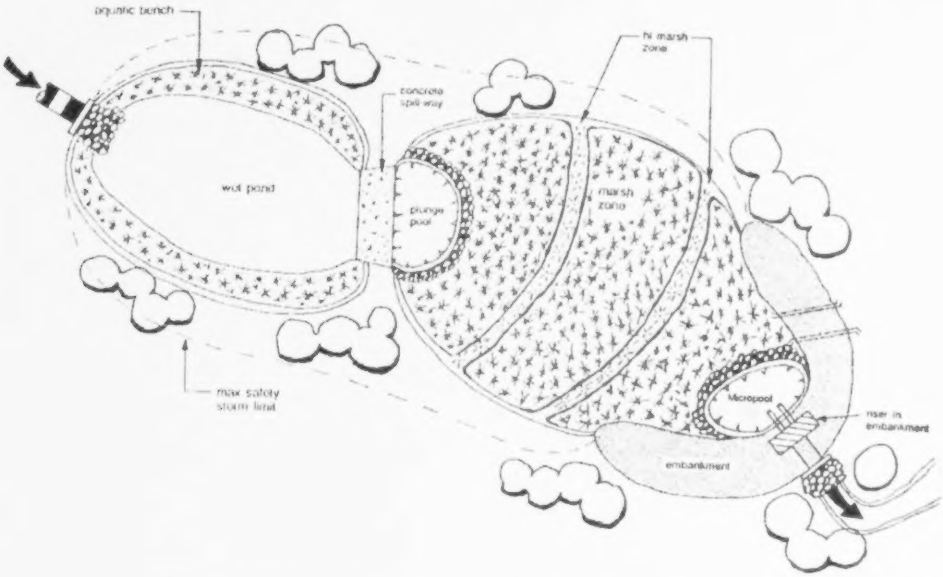

aquatic bench
hi marsh zone
concrete spill-way
wet pond
plunge pool
marsh zone
max safety storm limit
Micropool
riser in embankment
embankment

Figure 6.11: Pond-Wetland System (Schueler, 1992)

iii. Extended Detention (ED) Wetland

In an extended detention wetland, additional temporary storage is created above the shallow marsh area (see Figure 6.12). With this system, less space is required since temporary vertical storage is partially substituted for shallow marsh storage. As a result, a new vegetation zone is created between the normal water level and the high water level.

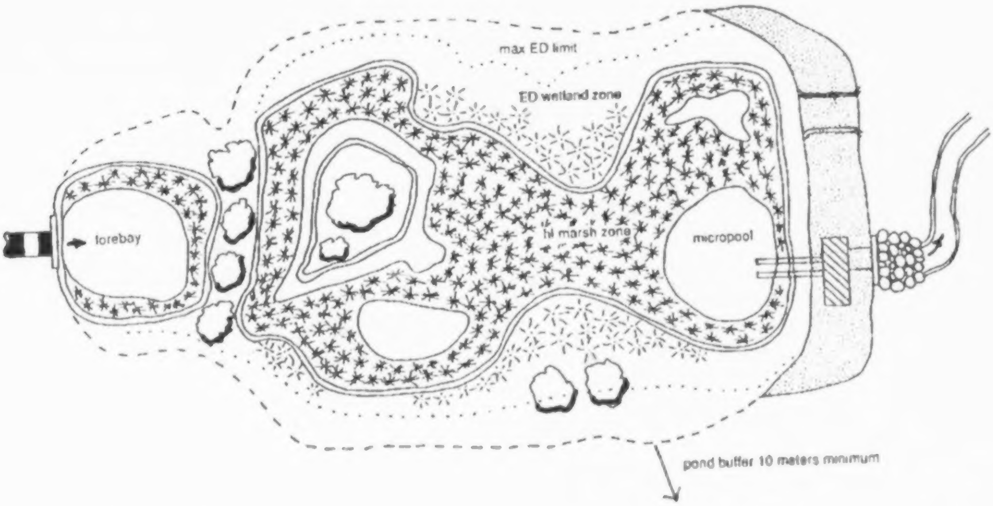


Figure 6.12: Extended Detention Wetland (Schueler, 1992)

This type of wetland design is highly suited to the Calgary region, since it can be designed to accommodate seasonal and year-to-year hydrologic cycle variations.

iv. Pocket Wetland

Pocket wetlands are adapted to serve smaller sites ranging from 0.4 ha to 4 ha. The systems are designed for widely fluctuating water levels since there may not be a reliable source of baseflow (see Figure 6.13). Some of the baseflow may be supported by excavating down to or below the water table. In drier areas, the pocket wetland may only be supported by stormwater runoff, and during extended dry periods, there may not be a shallow pool. Pocket wetlands often have low plant diversity, poor habitat value, and limited pollutant removal capability. To some extent, the pocket wetland mimics the prairie potholes that are common in Western Canada in terms of size and topography.

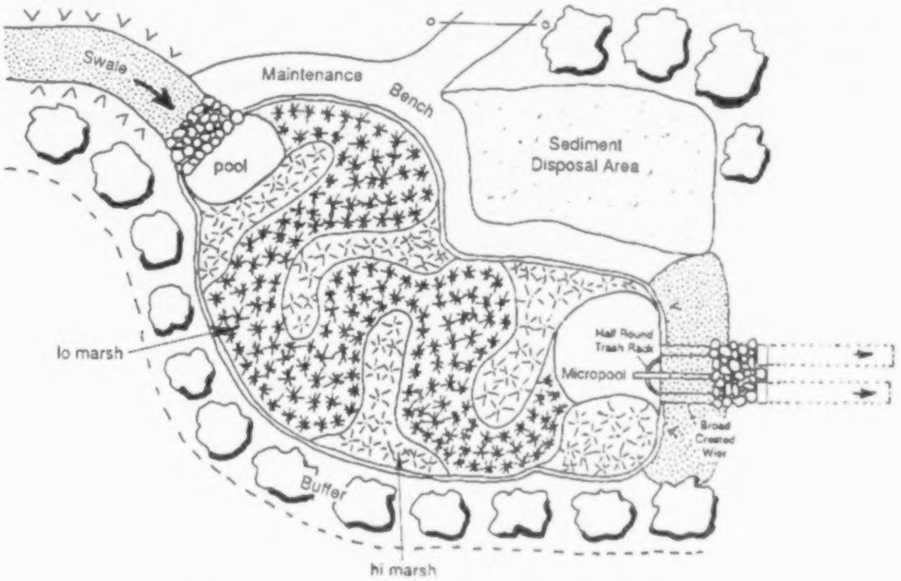


Figure 6.13: **Pocket Wetland (Schueler, 1992)**

v. Fringe Wetland

A fringe wetland is formed by constructing shallow aquatic benches along the perimeter of the permanent pool of a wet pond. The benches are usually 3 m to 5 m wide on both sides of the NWL. In Calgary, bench widths up to 10 m have been used.

Fringe wetlands are a useful design feature in ponds since they can be designed to promote a natural appearance, conceal trash and changes in water levels, reduce safety hazards, improve flow patterns and sediment removal, and provide some aquatic habitat.

vi. Others

There are other types of wetland systems or features that can be incorporated to further enhance water quality treatment:

A **Backflood Wetland, Meadow or Forest** is a type of meadow, shrub, or treed thicket area on the Canadian prairies. It can accommodate long periods of inundation during repeated storm events, wet years or major snow melts.

Shallow Overland Flow evenly dispersed over a meadow or thicket area may be useful downstream of a sedimentation pond where higher sediment removal rates are desired.

A **Shallow Soil Infiltration Bed** is a type of wetland based on a common natural landscape feature of the foothills and boreal forest region. Shallow soil filtration can provide higher sediment removal rates than ponds and better buffering of other pollutant concentrations (such as seasonal salt loading). Shallow soil filtration pertains to saturated conditions that are within the typical rooting depth of land plants (2 m).

Groundwater Infiltration refers to wetlands or portions of wetland systems that are designed as infiltration facilities. In this type of system, all or a portion of the inundated stormwater volume will percolate through the soil profile to become deep groundwater. Deep groundwater refers to the saturated conditions below the typical rooting depth of land plants (2 m).

6.4.2 Design

Table 6.3: Design Summary Guide for Wetlands

Design Element	Design Objective	Minimum Criteria	Recommended Criteria
Level of Service/ Volumetric Sizing	Provision of appropriate level of protection and adequate volume for quantity and quality	100 year design and 80% removal of TSS for water quality	
Land Dedication	Appropriate location	PUL, ER	PUL
Drainage Area	Function of permitted release rate. Maintain minimum orifice size, limit number of ponds, maximum pond volume	> 4 ha	≥ 10 ha
Pond Area/ Number of Ponds	Maximum pond area, Limit number of ponds	2 ha at NWL	
Water Quality	Pre-treatment	80% removal of TSS	
Sediment Forebay	Pre-treatment (sedimentation)	Area: 20% Max. Depth: 1 m Min. Appropriate Length and Width according to Section 6.3.2.8	10 % Max. 1.5 – 2 m
Forebay Length:Width Ratio	Maximize flow path and minimize short-circuiting	Min. 2:1 measured along flow path	
Active Storage Detention Time	Suspended Solids Settling	24 hours	
Length:Width Ratio	Maximize flow path and minimize short-circuiting	Min. 1:1	3:1
Pond Depth	Safety, Control of weed growth	Btm to NWL: 0.3 m Avg. 0.5 m Max. 25% Max. area Inlets/Outlets: 1 m Min. 3 m Max. NWL to HWL: 1 m Max. Freeboard: 0.15 m Min.	
Overland Routes	Safety	Meets Alberta Environment Depth-Velocity guidelines	
Escape Route	Safety	Min. 1 to 2 m^3/s	Maximum possible
HGL	To prevent backup	No surcharging to surface	HGL impact confined to pipe adjacent to pond

Design Element	Design Objective	Minimum Criteria	Recommended Criteria
Landscaping	Public Amenity & Safety	Approval of Wastewater & Drainage and Park Development & Operations	
Recreational Activities	Public Safety	See List in section 6.4.2.16	
Side Slopes	Drainage and Safety	Above HWL: 4H:1V to 5H:1V Max. Outward facing: 3H:1V Max. NWL to HWL: 5H:1V Max. Below NWL: 10H:1V Max. Terraced: 7H:1V and 3H:1V Benches: 150mm to 300mm drop	
Bottom Slope	Promote Sheet Flow	0.5 to 1 %	
Geotechnical	Infiltration	Max: 1 x 10^{-6} cm/s	
Inlet	Safety & Maintenance	Submerged: - Crown 0.8 m below NWL - Invert: 100 mm above btm. Unsubmerged: invert @ HWL Skimmer MH req'd	
Outlet	Safety & Maintenance	1.2 m x 1.2 m /chamber	1.8 m x 1.8 m /chamber
Orifice	Avoid Plugging	50 mm diameter	100 mm diameter
Trash Rack (Exposed Outlet)	Protect Orifice from plugging	Req'd when orifice ≤ 200 mm diameter	
Gate Valve	Bypass & Maintenance	Required (300 mm diameter)	
Maintenance Vehicle Access	Access for equipment	Width: 3.0 m Turning Radius: 8 m	4.0 m
Fencing	Safety	Not generally required	
Monitoring Equipment	Safety & Design	Required (see Section 6.1.9 and Appendix C)	
Signage	Safety	Required (see Appendix D)	

Note: Refer to detailed information provided in following sections

6.4.2.1 Overall Design Philosophy

Stormwater wetland construction in Calgary is relatively new and design is continually evolving. Despite a large amount of research and published information, the optimal design of a constructed wetland has not yet been determined. Many systems have not been adequately monitored or have not been operating long enough to provide sufficient data for analysis. As a result, Mitsch (1992) suggests the following guidelines for creating successful constructed wetlands:

- Keep the design simple. Complex technological approaches often invite failure.
- Design for minimal maintenance.
- Design the system to use natural energies, such as gravity flow.
- Design for the extremes of weather and climate, not the average. Storms, floods and droughts are to be expected, and planned for, not feared.

- Design the wetland with the landscape, not against it. Integrate the design with the natural topography of the site.
- Avoid over-engineering the design with rectangular basins, rigid structures and channels, and regular morphology. Mimic natural systems.
- Give the system time. Wetlands do not necessarily become functional overnight and several years may elapse before performance reaches optimal levels. Strategies that try to short-circuit the process of system development or to overmanage often fail.
- Design the system for function, not form. For example, if initial plantings fail, but the overall function is intact, then the system has not failed.

It should also be noted that hydrology is probably the most important factor in the establishment and maintenance of specific types of wetlands and processes (Mitsch and Gosselink, 1986). This includes precipitation, surface water inflow and outflow, groundwater exchange, and evapo-transpiration.

There are also some nuisance controls that should be considered:

- Mosquito control can be abated by introducing or making habitat available for baitfish, dragon flies, swallows and other predators.
- Nuisance wildlife, such as carp and muskrat, will require monitoring since they can destroy or consume wetland vegetation.
- Odour control is not usually required if stormwater wetlands are properly designed.

6.4.2.2 Level of Service/Volumetric Sizing

Wetlands must provide an active storage capacity for a 100 year return period storm. However, the wetland must also be sized to provide a minimum 80% removal of Total Suspended Solids (TSS) for particle sizes $\geq 75\mu m$ for water quality. The more conservative volume of the two criteria shall dominate. Refer to **Section 3.0 Stormwater Design** for more information.

There is no set **minimum** sizing criteria for the permanent pool (bottom to NWL) or the active storage (NWL to HWL). A minimum detention time of 24 hours must be provided. With active storage, the 100 year volume must be contained before spillover is permitted. Minimum design volumes should be based on generally accepted criteria.

Adequate area must be planned for a wetland. As a rule of thumb, Alberta Environment suggests that the wetland size be approximately 5%

of the watershed area it services. However, this is a planning tool only; **wetland size should be confirmed through modelling.** Depending on the type of wetland and requirements, sizing may be less than 5%. It is important to note that wetlands require a minimum amount of water to survive; while wetlands can usually tolerate temporary drawdowns, they cannot usually withstand complete drying. Therefore, water level control is important to maintaining a healthy wetland. Design can also provide for fluctuations for habitat management.

Release rates from the wetlands must conform to the rates set out in the approved Master Drainage Plan report and/or approved Staged Master Drainage Plan report.

6.4.2.3 Land Dedication

Wetland locations must be integrated with the Natural Areas Management Plan and approved by Park Development & Operations. Contact Park Development & Operations for more information. Also refer to "Calgary Open Space Plan" by Calgary Parks & Recreation (February 2000) for further information.

i. Wetlands that are to be ultimately operated by The City of Calgary are to be located on Public Utility Lots (PUL).

ii. The use of MR and MSR lands for wetlands will not be supported. Land located adjacent to public utility lands may be designated MR if the design of the pond provides a pathway or visual amenity.

iii. Use of ER may be supported if the wetland can function as part of the natural drainage system and can be appropriately designed and managed. Approval from Park Development & Operations is required.

iv. All forebays shall be located on PUL lands outside of the MR.

v. Retrofit wetlands may be supported in Major Natural Area Parks when there is minimal disturbance to the natural system. Approval from Park Development & Operations is required.

vi. Wetlands should not be located in river valleys unless there are no other viable locations.

viii. Where a wetland is located on privately owned land, an easement is required to permit encroachment of water onto the property and restrict development in the areas subject to inundation. For ponds proposed on provincial lands, approval is required from the Province of Alberta. Contact Alberta Environment for more information.

vii. A maintenance agreement is required for any **public (City owned)** wetland that will be operated and maintained by a private owner. Contact Wastewater & Drainage for further information.

viii. The maximum level of inundation, the high water level (HWL), must not encroach onto private property. Lots bordering the wetland are required to have abutting property elevations a minimum of 0.3 m above the spillover elevation of the pond.

ix. **Existing** wetlands that qualify for ESA (environmentally sensitive area) status may have limited suitability for dual use in stormwater management. Such sites will be managed for habitat and long term sustainability.

x. A Biophysical Impact Assessment (BIA) is required for wetlands identified as environmentally significant. Environmental Impact Assessments (EIA) are required to determine whether an existing wetland is environmentally sensitive.

6.4.2.4 Drainage Area

Wetlands require a minimum drainage area to sustain vegetation and the permanent pool. Refer to **Appendix F** for suggested minimum drainage areas. As a minimum, drainage areas ≥ 4 ha are recommended, with preference for 10 ha or larger. These minimum drainage areas have been targeted as a guideline. The drainage area will be a function of the permitted release rate, water quality requirements and minimum size.

6.4.2.5 Pond Area & Number of Ponds

The minimum area of a wetland shall be 2 ha at the normal water level (NWL). Smaller areas will only be considered on a site-specific basis at the discretion of Wastewater & Drainage. In such cases, the private owner may be required to enter into a private maintenance agreement.

From a maintenance perspective, economies of scale can be realized with fewer and larger wetlands. The developer shall make every effort throughout the planning process to limit the number of wetlands required.

6.4.2.6 Winter Operation

Due to its shallow depth, much of a wetland's permanent pool volume will be frozen during the winter. Therefore, treatment will be a function of the remaining active storage volume. In general, the performance of the wetland decreases when the wetland is covered with ice. While there are currently no requirements to compensate for the loss of volume due to ice cover, precautions should be taken to minimize the effects of freezing of pipes and orifices.

6.4.2.7 Water Quality

All wetlands are required to provide enhanced water quality. Wetlands are to be sized to provide a minimum 80% removal of Total Suspended Solids (TSS) for particle sizes ≥75μm. For more information on particle size and settling velocities for modelling purposes, refer to **Section 7.5.3.2**.

Currently, there is no set **minimum** sizing criteria for the permanent pool (bottom to NWL) or the active storage (NWL to HWL). However, a minimum detention time of 24 hours must be provided. With active storage, the 100 year volume must be contained before spillover is permitted. Minimum design volumes should be based on generally accepted criteria.

Water quality monitoring is also required during the maintenance period (See **Section 7.8**). Contact the Water Quality Engineer (Wastewater & Drainage) for more information. Costs of the program are to be covered by the developer during the maintenance period.

There are several mechanisms that are available in a wetland to improve water quality. These include:

- settling of suspended solids
- filtration and chemical precipitation through contact of the water with the substrate
- chemical transformation
- adsorption and ion exchange on the surfaces of plants, substrates and sediment
- breakdown and transformation of pollutants by microorganisms and plants
- uptake and transformation of nutrients by microorganisms and plants
- predation and natural die-off of pathogens

6.4.2.8 Sediment Forebay

A sediment forebay facilitates maintenance and improves pollutant removal of larger particles near the inlet of the wetland. In a wetland, it is important to confine sedimentation to the forebay since vegetation in the wetland area restricts sediment removal maintenance. The forebay should be one of the deeper areas of the pond to minimize the potential for particle re-suspension and protect the wetland from sedimentation.

Sediment forebays are required on all wetlands. The forebay must be included as a separate facility from the wetland. As well, each inlet must drain into the forebay; short-circuiting through the forebay should be avoided. Only the Pond-Wetland system does not require a separate forebay since the wet pond cell acts as the forebay.

Sizing

Sizing of the forebay length and width is determined using the same method provided for wet ponds (**see Section 6.3.2.8**). The forebay area should not exceed 20% of the overall wetland area (including the forebay); the preferable forebay area is approximately 10%.

Depth

The minimum depth of the sediment forebay should be 1 m to minimize the potential for scour and re-suspension. The recommended depth is 1.5 m to 2 m.

Length: Width Ratio

The total length of the forebay should provide a length to width ratio ≥ 2:1 for each inlet. A length to width ratio < 2:1 is undesirable since the storage will not be utilized effectively. In this case, the addition of flow baffles, or other means of lengthening the flow path in the forebay, may be used, subject to approval by Wastewater & Drainage. When lengthening methods are used, effective length is measured along the flow path.

6.4.2.9 Forebay Berm

An earthen berm should be used to separate the forebay from the rest of the pond. The berm height should be set between 0 and 0.3 m above the permanent or normal water level elevation (NWL). The berm should be constructed with a solid substrate to facilitate removal of accumulated sediment and debris.

Emergent vegetation should be planted along the berm to promote filtration of water as it passes over (see **Appendix E** for species). The plants should be established on the top and sides of the berm at a maximum planting depth of 30 cm.

If possible, a maintenance pipe should be installed in the forebay to allow drawdown of the forebay for maintenance purposes. The maintenance pipe should be connected to a bypass pipe around the pond. Otherwise, the forebay will have to be pumped out. If only the forebay is to be pumped out or drawn down during maintenance, the forebay berm must be designed as a small dam since the rest of the pond will not be drained. Care must be taken not to compromise the structural integrity of the berm or liner during drawdown conditions.

6.4.2.10 Detention Time

A minimum detention time of 24 hours is required to promote water quality enhancement for active storage. Detention time is defined as the theoretical time required to displace the contents of a stormwater pond at a given rate of discharge (ie. volume divided by rate of discharge).

6.4.2.11 Length:Width Ratio

The flow path through a wetland is important to its overall performance. In a wetland, the flow path is dependent on the plantings and grading within the wetland due to the shallow depth of the permanent pool. The length should be based on the low flow path through the wetland rather than the overall length dimension of the wetland. Low flow paths should be created in the wetland to ensure short-circuiting does not occur.

The minimum length to width ratio is 1:1. However, the preferred length to width ratio is 3:1. Effective length excludes forebay length.

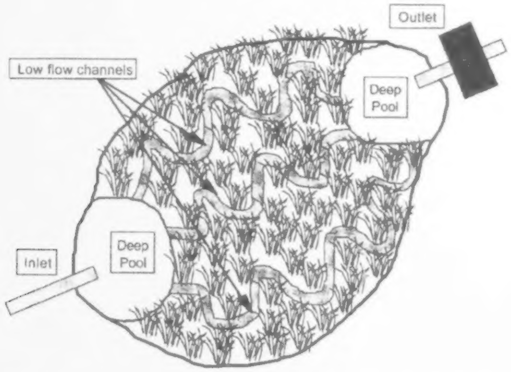


Figure 6.14: Extending Flow Path through a Wetland

Where possible, all stormwater servicing should be conveyed to one inlet location in the forebay. To provide the longest flow path though the pond, the inlet should be located as far away from the outlet as possible.

The provision of additional berms in the wetland to redirect flows and lengthen the flow path is also acceptable to ensure short-circuiting will not occur.

6.4.2.12 Pond Depth

The depths of the permanent and active storage areas are important to the design and function of the wetland. Controlling water levels will help maintain a healthy wetland while providing water fluctuations in the design can provide habitat management.

Permanent Storage Area

The **average** permanent pool depth measured from the pond bottom to NWL should be 0.3 m. The **maximum** permanent pool depth should not exceed 0.5 m.

Water depth at the inlets and outlets should be ≥ 1 m to minimize sediment re-suspension. The maximum depth should be limited to 3 m.

Pockets of deep zones in the wetland up to 1 m are permitted for flow redistribution and submerged or floating aquatic vegetation. In general, the deep areas in a wetland should be limited to 25% of the total surface area to ensure that the majority of the wetland sustains emergent vegetation. Only the Pond-Wetland design will contravene this criterion due to the wet pond portion.

Active Storage Area

The **maximum** active storage depth shall be 1 m. The active storage depth is defined as the depth between NWL and HWL and is often referred to as the extended detention portion. In addition, a minimum freeboard of 0.15 m is required above HWL.

Some plant species cannot withstand water level fluctuations greater than 1 m. Although 1 m is sufficient for most wetland designs, the depth should be based on the plant species chosen.

6.4.2.13 Overland Drainage Routes

i. Overland drainage routes that direct flows from the 100 year storm event to the pond area shall be provided. Overland flow design velocities (v) and depths (d) must be in accordance with "Stormwater Management Guidelines" for the Province of Alberta (January 1999). See **Table 3.15 and Figure 3.9**. Erosion control needs must be evaluated.

ii. An emergency overland escape route from all ponds is to be provided. In general, the escape route must provide a minimum capacity between 1 and 2 m^3/s. Appropriate capacity should be determined at the time of design.

Optionally, additional freeboard may be considered in cases where it is difficult to establish an escape route. The additional freeboard would provide a higher level of service overall.

iii. Sanitary sewer manholes must be located outside of impoundment (pond) areas. Whenever possible, sanitary sewer manholes should not be located within the overland drainage route.

iv. Sanitary sewer manholes located within overland drainage routes must be sealed. Bolting is at the discretion of Wastewater & Drainage.

6.4.2.14 Hydraulics

The 100 year elevation will be established taking into consideration the adjacent footing elevations. When the wetland is at the 100 year elevation, water should not back up through the storm sewer and weeping tile connections to create hydraulic pressure on foundations. Areas affected by the HWL and resulting hydraulic grade line should be kept to a minimum. Free flow conditions are preferable; this is achieved when the crown of the closest incoming storm sewer(s) is at or above the HWL. All hydraulic conditions must be approved by Wastewater & Drainage. Refer to **Section 5.0 Hydraulic Design** for more information.

When free flow conditions are not achieved based on the HWL, hydraulic grade line (HGL) elevations in the storm sewers must be determined based on the wetland at HWL and the appropriate losses taken into account (ie. junction losses, pipe losses, etc.). **Surrounding footing (or slab) elevations must be a minimum of 0.3 m above the HGL.** Other options to protecting weeping tile connections include a separate weeping tile system connected downstream of the wetland, or sump pump to surface. Weeping tile connected to sanitary is not permitted in any circumstances.

Surcharging to ground surface will **not** be permitted. Contact Wastewater & Drainage for further information.

Backflow prevention devices are required on all weeping tile connections as per the Alberta Plumbing Code.

All upstream storm piping below the HWL and HGL must be rubber gasketed.

6.4.2.15 Landscaping & Vegetation

Landscaping and vegetation plans must be submitted with the construction drawings. The drawings must be reviewed and approved by Wastewater & Drainage and Park Development & Operations. All landscaping must be prepared by a qualified consultant and must conform to "Development Guidelines and Standard Specifications-Landscape Construction" (latest issue) by Calgary Parks & Recreation. Qualified consultants should also be knowledgeable in wetland ecosystems. Refer to **Appendix E for Recommended Plant Species**.

A planting strategy is required to provide shading, aesthetics, safety, enhanced pollutant removal and waterfowl control. The purpose of the planting is to provide a sustainable community with a **naturalized treatment**. Plants native to Calgary should be used where possible. Planting density may not have to be high, as natural succession will ultimately make up the vegetation. As well, the overall planting should be designed to minimize maintenance. Manicured and mown areas should be kept to a minimum or discouraged, as these areas can attract birds and geese and become a problem.

For a list of plant species, refer to **Appendix E**.

The primary difference between wetlands and wet ponds, in terms of landscaping and vegetation, is the proportion of shallow areas and deeper areas. Therefore, the planting strategy for the different types of areas (ie. deep, shallow, fringe, and upland) for wetlands is the same as for wet ponds. Refer to **Section 6.3.2.15** for design information.

6.4.2.16 Recreational Activities

Constructed stormwater wetlands can enhance the environmental features in an urban area. Although wetlands provide some recreational benefits, these benefits are quite different from wet ponds. As with wet ponds, there are potential risks associated with these activities.

Contact with stormwater in a wetland can cause skin irritation (swimmer's itch) and ingestion can make people ill. Since the water quality in a wetland does not generally meet the Alberta Environmental Protection Act (EPA) Guidelines, activities that involve direct water contact are prohibited.

Prohibited activities include swimming and wading. Also prohibited is use of motorized boats since this activity is a potential source of noise, nuisance, and petroleum product spills. The exception is the use of motorized boats for emergency or maintenance purposes. Due to the significant vegetation and marshes, secondary activities are also prohibited. Secondary activities include non-motorized boating activities such as kayaking, canoeing, paddle boating, rafting and model boating.

Only Tertiary activities are permitted. These include:

- Photography
- Bird watching
- Bicycle riding
- Jogging
- Walking
- Outdoor picnicking
- Arts and crafts

Ice related activities, such as skating and cross-country skiing, are not supported since the ponds are not monitored for ice thickness. As well, protruding wetland vegetation will interfere with these types of activities. For further information, contact Wastewater & Drainage Services.

6.4.2.17 Grading/Slopes

Grading and landscaping of the wetland and adjacent areas is important for public safety and the functionality of the wetland. Due to evolving wetland design, flexibility in grading will be permitted subject to approval by Wastewater & Drainage.

Side Slopes

i. Due to the nature of the permanent pool and extended detention depths, grading in a wetland should be reasonably flat.

ii. Grading above the HWL shall be 4H:1V to 5H:1V maximum. For outward facing slopes, grading shall not exceed 3H:1V.

iii. Grading between pond bottom and NWL should not exceed 10H:1V. See Figure 6.15.

iv. Grading between NWL and HWL (extended detention area) should not exceed 5H:1V. See Figure 6.15.

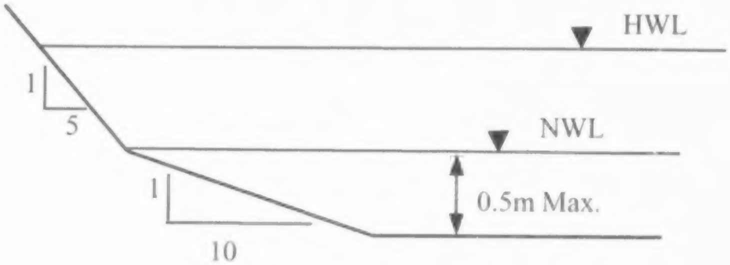

HWL
NWL
1
5
1
10
0.5m Max.

Figure 6.15: Typical Side Slopes for Wetlands

v. Terraced grading is recommended to minimize the potential for public to fall into the wetland. For terraced grading, alternating sections of 7H:1V and 3H:1V should be used in the vicinity of NWL. See Figure 6.16.

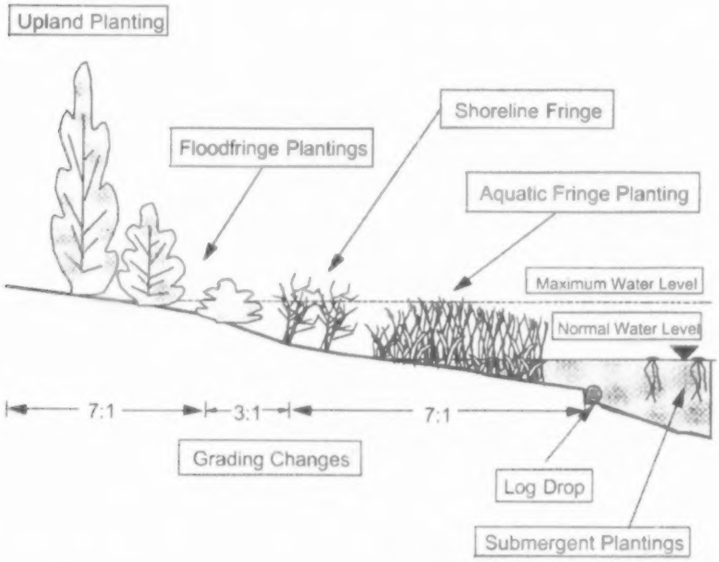

Upland Planting
Shoreline Fringe
Floodfringe Plantings
Aquatic Fringe Planting
Maximum Water Level
Normal Water Level
7:1
3:1
7:1
Grading Changes
Log Drop
Submergent Plantings

Figure 6.16: Terraced Side Slopes for Wetlands

vi. Alternative side slope designs will be considered. This includes aquatic benches to enhance vegetation and naturalization. Small drops of 150 mm to 300 mm can be incorporated to serve as a warning to public accessing deeper water. Contact Wastewater & Drainage for approval.

vii. Where possible, grading should be designed to replicate the natural landform.

Bottom Slopes

In general, a bottom slope of 0.5 to 1% along the flow path is recommended to promote sheet flow through the system. Bottom slopes may be flatter provided positive flow towards the outlet is achieved.

6.4.2.18 Geotechnical

A geotechnical report must be undertaken by a qualified geotechnical consultant that addresses issues related to the design of the wetland. The purpose of the report is to determine criteria such as dam safety (as required), underdrainage design (ie. toe drains), liner requirements (infiltration), and any other special design conditions such as slope stability. See **Section 6.1.6**.

Pond bottom material is to be composed of impervious material with a suitable low permeability (permeability coefficient in the order of 1×10^{-6} cm/s). Preference should be given to using clay where possible or an acceptable alternative; puncturing of liner materials during sediment removal is a concern. Organic soils are not permitted.

The report must be submitted and approved by Wastewater & Drainage Services prior to submission of the construction drawings. The geotechnical report should be submitted with the Stormwater Pond report, the Master Drainage Plan report, or the Staged Master Drainage Plan report, whichever is the most practicable. Required details must be indicated on the construction drawings.

Geotechnical reports shall be submitted to Alberta Environment, Municipal Approvals, at the pre-design stage for stormwater ponds that may be classified as a dam (see **Section 2.3.3.1**); approval under the Water Act is required. Drawings of the pond shall also be submitted. Municipal Approvals will forward the information to the Dam Safety and Water Projects Branch as part of the review process. Contact Alberta Environment, Municipal Approvals for more information.

6.4.2.19 Inlet(s)

Due to the design and function of a wetland, an inlet is the only type of structure that permits the inflow of stormwater into the wetland. In order to provide water quality treatment, the flow must go through the wetland to the opposite end.

i. Inlets should **not** be located close to the outlet control structure to minimize short circuiting.

ii. Ideally there should only be one discharge location, or inlet, into the wetland. Multiple inlets should be avoided where possible.

iii. It is preferable that all inlets and outlets be fully submerged with the crown of the pipe a minimum of 0.8 m below NWL. See Figure 6.9. However, due to the shallowness of wetlands, this is not always possible.

iv. Unsubmerged inlets may be used provided the pipe invert is set at the maximum design level (HWL) of the wetland. With this design, erosion control is required between the HWL and NWL. See Figure 6.17.

v. Inlet and outlet pipe inverts are to be a minimum of 100 mm above the pond bottom; depths in excess of 100 mm are recommended to prevent sedimentation from blocking the inlet pipe. Erosion control measures must be provided at the bottom of the inlet structure(s) to control erosion and scour. Erosion control measures should include the installation of a hard-bottomed surface, interlocking stone, or an approved concrete revetment/armouring system near the inlet pipe. Other enhancements such as dissipators or deflection structures will help minimize scour and re-suspension.

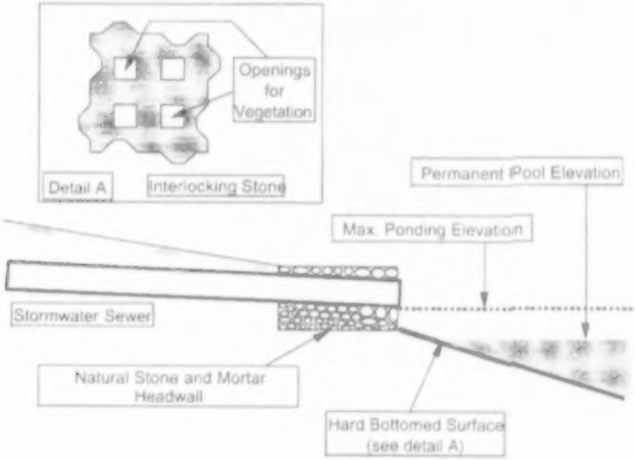

Openings for Vegetation
Detail A
Interlocking Stone
Permanent Pool Elevation
Max. Ponding Elevation
Stormwater Sewer
Natural Stone and Mortar Headwall
Hard Bottomed Surface (see detail A)

Figure 6.17: Unsubmerged Inlet

vi. Inlet velocities should be limited to 1.5 m/s where possible to minimize erosion and scour, and re-suspension of sediments.

vii. The invert elevation of the inlet pipe(s) to the first manhole upstream from the wetland shall be at or above the normal water level (NWL) of the pond to avoid deposition of sediments in the inlet and freezing problems.

viii. A skimming type manhole or approved equivalent must be constructed on the first manhole upstream of the inlet(s). The purpose of the skimming manhole is to collect floatables (hydrocarbons, paint, etc.) and debris prior to entering the pond.

ix. Gratings are not required on submerged inlets. However, unsubmerged inlets do require gratings.

x. Rock lined channels that convey stormwater from a pipe outlet to the wetland should be avoided.

6.4.2.20 Outlet Control Structure

Typically, the outlet control structure serves as the source of control for the release of stormwater from the wetland and the preservation of the normal water level elevation. The outlet structure is commonly referred to as the control structure or the outlet control structure. It is important that the structure be properly designed and constructed to provide minimal maintenance and enhance safety. Design of the control structure must be approved by Wastewater & Drainage. See **Sections 5.4** and **5.5** for additional design information.

Different types of control structures may be used for a wetland:

i. Three chamber structure- This type of control structure is most commonly used. In this type of structure, there are usually two weir walls, one to control the normal water level (NWL) and one to control the high water level (HWL). Other control structure designs may include two chambers. For maintenance purposes, the size of each chamber should be a minimum of 1.2 m. However, the desired size is 1.8 m.

ii. Reversed Slope Pipe- The reversed slope pipe should drain to an outlet chamber located in the embankment. It is recommended that a gate valve be installed at the outlet end in the chamber to allow the drawdown time to be modified for future operating conditions.

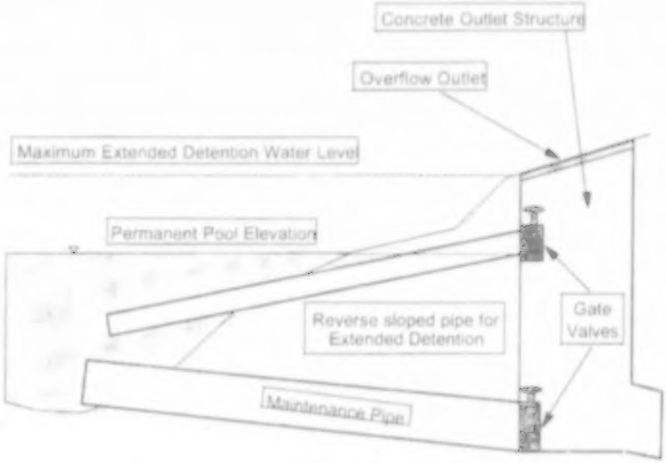

Concrete Outlet Structure
Overflow Outlet
Maximum Extended Detention Water Level
Permanent Pool Elevation
Reverse sloped pipe for Extended Detention
Gate Valves
Maintenance Pipe

Figure 6.18: Reversed Slope Pipe Outlet

Orifice

Usually an orifice provides the control for the permitted release rate for the wetland. The recommended minimum orifice diameter is 50 mm. This is to minimize the occurrence of clogging at the outlet. The preferred minimum diameter is 100 mm.

Where small orifices are required, consideration should be given to providing an overflow outlet that would operate in the event of blockage of the primary orifice.

The orifice plate should be constructed of galvanized steel or an approved equivalent.

Weir Walls

The three chamber control structure will typically have two weir walls: one to control the normal water level (NWL) and one to control the high water level (HWL) to provide a source of overflow for the pond in the event of a blockage of the orifice. The weir wall controlling the overflow should be set at the HWL elevation, or the calculated hydraulic grade line elevation.

Trash Rack

A trash rack may be required depending on the design of the outlet pipe and/or outlet control structure. A submerged outlet pipe and/or outlet control structure will not require a trash rack.

For an exposed outlet control structure, a trash rack must be installed to protect the orifice when the diameter is ≤ 200 mm. The trash rack must be galvanized and include an access to the orifice for maintenance purposes. The openings in the trash rack must large enough to prevent clogging on a frequent basis, yet small enough to provide protection to the orifice. Vegetation may contribute to the potential for clogging. Typically, an opening 25 to 50 mm smaller than the orifice diameter is suitable. Since the drainage area to a wetland is usually large, the diameter of the orifice is usually large enough so that a trash rack is not required.

Gate Valves

All wetlands require a gate valve. The gate valve is used as a bypass for the orifice in the event the orifice plugs, and for maintenance purposes. Although there is no set size specified, a minimum gate size of 300 mm diameter should be targeted where possible. Consideration should be given to not exceeding the design flow in the downstream storm pipe, except in emergency situations.

With the three chamber design, two bypass gate valves are required, one in the NWL weir wall and one in the HWL weir wall.

In the reversed slope pipe design, the maintenance pipe should drain to the outlet chamber. A gate valve is required on the end of this pipe. Outlet flows can be controlled by setting and fixing in place gap openings.

All gates should have non-rising stems that are operated mechanically, or manually with a T wrench. The T wrench should be located on the downstream end of the control structure in an easily accessible location.

The use of automatic control gate systems is not advocated. Wastewater & Drainage will review these designs on a site-specific basis only. An Operating and Maintenance manual is required for all automatic control gate systems.

Hydraulics

The hydraulic performance of the control structure is important to its operation. Hydraulic calculations should be provided where possible. Refer to **Section 5.0 Hydraulic Design**.

6.4.2.21 Maintenance Vehicle Access

i. Maintenance vehicle access from an adjacent street or lane must be provided to the control (or outlet) structure, and to the inlet structure(s) of the wetland. The sediment forebay must also be readily accessible for maintenance purposes.

ii. The vehicle access route must be a minimum of 3.0 m wide, but preferably 4.0 m wide. The surface must be driveable.

iii. Sharp turns are to be avoided; the minimum turning radius is 8 m.

iv. Suitable surfacing material is to be used (ie. pavement, gravel, etc.) The subgrade for the access route must be able to withstand a 13 tonne vacuum truck. The subgrade must conform to "Standard Specifications Streets Construction" by Streets (latest edition). Alternatives will be considered subject to approval by Wastewater & Drainage.

6.4.2.22 Fencing

In general, full perimeter fencing is not desired, unless required by Park Development & Operations or other business units. If there is a concern for safety due to the pond being in a remote location, fencing may be requested. Most wetlands provide amenities that must be accessible to the public. Alternatives such as the strategic planting of vegetation to provide effective barriers are advocated. However, some facilities may be more susceptible to damage caused by prohibited vehicles. In these situations, sections of the pond may be protected by post and cable fencing, gates, bollards, or other approved alternatives.

Safety railings should be confined to critical areas where safety is a concern. This includes areas where the vertical drop is ≥ 1 m. Chain link fence is less desirable than safety railings and is only acceptable when the attached fencing does not protrude above the top rail.

Any required fencing must be in accordance with "Development Guidelines and Standard Specifications-Landscape Construction (latest issue) by Park Development & Operations.

6.4.2.23 Monitoring System

Remote water level monitoring equipment is required at all wetlands to allow level monitoring by Wastewater & Drainage staff (Systems Maintenance and Design) when the pond is being used for storage. The equipment shall be installed at the developer's expense. See **Section 6.1.9** and **Appendix C** for details.

6.4.2.24 Signage

All wetlands are required to have appropriate signage. Signage is required at all entrances to the wetland and at any other critical points. Locations should be identified on the Site/Overall pond drawing. See **Appendix D** for sign requirements. The developer is responsible for the cost of purchasing and installation. Arrangements can be made with Wastewater & Drainage (Systems Maintenance) to order and/or install the signs.

As well, an information sign (see **Appendix C**) is required at the most prominent entrance to the wetland. The purpose of the sign is to inform people about the function of the wetland, and to provide a contact number for further information or to report problems. It is the responsibility of the developer to supply and install the sign.

Signs promoting public education are encouraged. Signs may include information regarding operation and purpose of the pond, protection of the environment, water conservation, native landscaping, impact of chemicals and interpretative trails. Contact Wastewater & Drainage and/or Park Development & Operations for more information.

6.4.2.25 Public Education

It is the responsibility of the developer to provide an education brochure on stormwater wetlands during the marketing of an area that includes a wetland. The purpose of the brochure is to educate residents on:

- the specific function of stormwater wetlands
- the water quality inherent with the function of the wetland and the impact of water quality resulting from fertilizers (which indirectly feeds into the sewer system by surrounding residents)
- permitted recreational uses
- maintenance concerns and the potential for increased maintenance charges to residents to increase the level of maintenance deemed necessary

Wastewater & Drainage will undertake an annual distribution of a door hanger with the above information to communities with a wetland. Distribution will start after construction of the pond.

6.4.2.26 Enhancements

In general, Wastewater & Drainage will not fund any enhancements outside of the design specified above. This includes water fountains, aerators, waterfalls, boat docks, etc. Stormwater wetlands should be kept in as natural a state as possible. Contact Wastewater & Drainage for more information.

7.0 Water Quality

7.1 General

In the past, there has been a tendency to regard stormwater as a relatively minor source of pollution. However, numerous studies have indicated that there can be significant pollution in stormwater runoff. The annual loadings from urban runoff can be similar to those found in wastewater effluent and industrial discharges. Urban runoff is typically high in suspended solids and biochemical oxygen demand (BOD), and can contribute significant concentrations of toxic metals, salts, nutrients, oils and grease, bacteria, and other contaminants to receiving waters. As a result, this may impact the potable water supply, aquatic habitat, recreation, agriculture, and aesthetics.

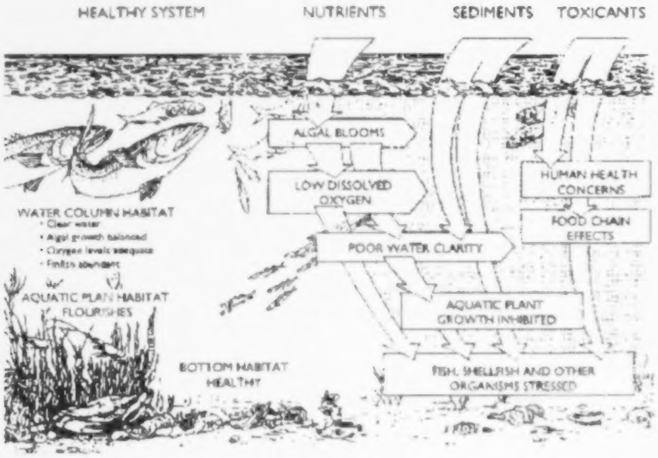

HEALTHY SYSTEM
NUTRIENTS
SEDIMENTS
TOXICANTS
ALGAL BLOOMS
LOW DISSOLVED OXYGEN
HUMAN HEALTH CONCERNS
FOOD CHAIN EFFECTS
POOR WATER CLARITY
WATER COLUMN HABITAT
• Clear water
• Algal growth balanced
• Oxygen levels adequate
• Finfish abundant
AQUATIC PLAN HABITAT FLOURISHES
AQUATIC PLANT GROWTH INHIBITED
BOTTOM HABITAT HEALTHY
FISH, SHELLFISH AND OTHER ORGANISMS STRESSED

Figure 7.1: Effects of Pollutants on Aquatic Habitat

Although the natural environment has some ability to mitigate and adapt to the impacts of pollution, urban runoff management is required. Generally, urban stormwater is a controllable source of pollution which can be managed with the implementation of Best Management Practices (BMPs). It is important that BMPs include both source control and treatment approaches. Source control BMPs are the first practical step to be taken to enhance urban runoff quality. Treatment BMPs such as wet ponds and wetlands will be required when the runoff quality does not meet design specifications. On a smaller scale, vegetated swales, filter strips, and buffer strips can be considered.

7.2 Declining Water Quality

The discharge of uncontrolled stormwater may impact and alter the hydrological condition of the receiving water. Stormwater runoff can contain a wide variety of contaminants, often at concentrations exceeding water quality objectives. The chemical makeup is primarily dependent on the land use within the catchment and the location of atmospheric pollution caused by major industries or large developments. In general, the quality of stormwater discharge will deteriorate when the percent imperviousness and runoff volume increases. See Table 7.1 for typical pollutant concentrations found in urban stormwater.

Table 7.1: Typical Pollutant Concentrations Found in Urban Stormwater

Typical Pollutants Found in Stormwater Runoff	Units	Average Concentration(1)	Limits for Protection of Aquatic Life(2)
Total Suspended Solids(a)	mg/l	80	10 if background ≤100 mg/l, 10% of background if background >100 mg/l
Total Phosphorus(b)	mg/l	0.30	0.005-0.015(3)
Total Nitrogen(a)	mg/l	2.0	no data
Total Organic Carbon(d)	mg/l	12.7	no data
Fecal Coliform Bacteria(c)	MPN/100 ml	3600	no data
E.coli Bacteria(c)	MPN/100 ml	1450	no data
Petroleum Hydrocarbons(d)	mg/l	3.5	no data
Cadmium(e)	µg/l	2	0.3[USEPA]
Copper(a)	µg/l	10	7[Alberta]
Lead(a)	µg/l	18	30[CCME]
Zinc(e)	µg/l	140	30
Chlorides(f) (winter only)	mg/l	230	860[USEPA]
Insecticides(g)	µg/l	0.1 to 2.0	no data
Herbicides(g)	µg/l	1 to 5.0	no data

(1) These concentrations represent mean or median storm concentrations measured at typical sites and may be greater during individual storms. Also note that mean or median runoff concentrations from stormwater hot spots are 2 to 10 times higher than those shown here.

(2) Maximum concentrations for the protection of freshwater aquatic life as reported in "Approved and Working Criteria for Water Quality", B.C. Ministry of Environment (1989), when the receiving water hardness is 50 mg/l $CaCO_3$ (average for Fraser River in Lower Mainland). Values identified by notations USEPA, Alberta and CCME are reported from "Surface Water Quality Guidelines for Use in Alberta", Alberta Environmental Protection (November 1999).

(3) For lakes with salmonids as the predominant fish species

Units: mg/l = milligrams/liter µg/l = micrograms/liter MPN = Most Probable Number

Data Sources: (a) Schueler (1987) (b) Schueler (1995) (c) Schueler (1997) (d) Rabanal and Grizzard (1996) (e) USEPA (1983) (f) Oberts (1995) (g) Schueler (1996)

Sources: "Maryland Stormwater Design Manual-Volumes I & II", Maryland Department of the Environment, 1998, "Urban Runoff Quality Control Guidelines for British Columbia", BC Environment, 1992, and "Surface Water Quality Guidelines for use in Alberta", Alberta Environmental Protection, 1999.

Common pollutants found in stormwater include:

Suspended Solids

Sediment loading is the most predominant pollutant associated with stormwater runoff. Typically, the major source of suspended solids in urban runoff is eroded soil from construction activities. However, sediment deposited on impervious surfaces and highway/road runoff also contributes to the problem. The sediments, both suspended and deposited, can have adverse effects on aquatic life, and alter the conveyance and storage capacities in streams, lakes and rivers. The sediments may also transport other attached pollutants. Some receiving streams are more sensitive to sediment loading than others.

Nutrients

Urban runoff has elevated concentrations of both phosphorus and nitrogen. High nutrient loadings can lead to eutrophication of receiving waters; the excess nutrients promote algal growth and reduce the dissolved oxygen in the water body. The primary sources of phosphorus and nitrogen in urban runoff are decaying organic matter originating from vegetation and animals, and fertilizer applications.

Organic Contaminants

Organic pollutants in urban runoff include pesticides, herbicides, fossil fuel combustion by-products, plastic products, and automobile-related activities. Industrial facility activities can contribute to these organic pollutants. The most commonly studied organic contaminant in urban runoff appears to be hydrocarbons, particularly PAHs (polyaromatic hydrocarbons). Primary sources of PAHs are related to the operation of motor vehicles, mainly from combustion byproducts, tire wear particles, and used crankcase oil. Organic contaminants can be toxic to aquatic life.

Trace Metals

Many contaminants in stormwater can be toxic to aquatic life at certain concentrations; the contaminants can also accumulate in the sediments of streams, rivers and lakes. Major sources of metals appear to be related to the operation of motor vehicles, which includes exhaust emissions, oil and grease, corrosion, and the breakdown of the road surface. These may contribute zinc, copper, chromium, cadmium, nickel and lead. Pigments in paint and stain may contain chromium, lead and zinc. Various industries can also be sources of metals.

Microorganisms and Pathogens

Pathogenic microorganisms in stormwater can often be at levels above water quality objectives. The major sources of these organisms may be due to cross-connected sanitary systems or combined sanitary systems, or from animal and bird waste.

Elevated levels of fecal coliform bacteria such as E.coli can result in recreational impairment or closure of water bodies.

Salt

The application of rock salt to roadways during winter for de-icing purposes, is a major source of sodium and chloride irons. In turn, this may affect the water chemistry of the receiving water in terms of alkalinity, hardness, pH and salinity. Although the salt concentrations are generally not high enough to be directly toxic to fish and invertebrate species, the growth of aquatic plant species can be negatively affected.

Water Temperature

Stormwater runoff from impervious surfaces may increase the temperature in receiving waters. This may adversely limit the habitat viability of aquatic fish and invertebrates that require cool and cold water temperature conditions.

7.3 Need for Improved Water Quality

Due to the site-specific nature and inconsistent quality of urban runoff, accurate long-term characterization of discharges is difficult. However, it is clear that runoff from urban areas and highways contain relatively high concentrations of pollutants which can pose a threat to the health of organisms in receiving waters. Therefore, there is a need to implement water quality control and treatment of urban stormwater. Goals and objectives should reflect the threat to resources and the receiving water uses, and should include site-specific, measurable targets for parameters. Monitoring and analysis of the existing environment is required to evaluate the need for action and the type of action required to meet the goals and objectives. The existing conditions can then be used as a baseline for comparison to ongoing monitoring data.

Detention ponds, in particular wet ponds and wetlands, are the most common methods to enhance the water quality of stormwater runoff. The buffering and attenuation of stormwater flows contributes to the level of pollution control provided. However, it should be noted that the mechanisms that control pollutant removal, and in effect water quality, can be complex and numerous. In general, treatment ponds are effective in removing solids, but less effective for removing BOD (Biochemical Oxygen Demand), TP (Total Phosphorus), and TN (Total Nitrogen). Source controls can also be an effective means of limiting these contaminants.

Other Best Management Practices (BMPs) can be utilized to enhance water quality (see **Section 8.0 Best Management Practices**). However, the use of treatment BMPs for urban stormwater is relatively young technology, and the long-term effectiveness and impacts remain largely unknown.

7.4 Regulatory Requirements

7.4.1 Present

As of November 1998, the City of Calgary and Alberta Environment have agreed to provide improved water quality treatment for urban runoff. The current objective is to provide a minimum of 80% removal of total suspended solids (TSS) for particle sizes $\geq 75\mu m$. All new Master Drainage Plan areas from this date forward are to address water quality enhancement. Site specific areas are also required to address water quality enhancement. This may include, but is not limited to, industrial, manufacturing and commercial sites (see **Sections 4.11** and **4.12** for details). Contact Wastewater & Drainage for more information.

7.4.2 Future

The current water quality standard is only a temporary measure. **In the future, the water quality standard for urban runoff will be more stringent as the City heads towards a pollutant loading mandate.** As part of the City's requirement to meet provincial regulatory requirements, section 5.2 of the City's Wastewater & Drainage approval states:

"The City of Calgary shall plan, design, construct and manage the operation of the drainage system to comply with the limits for the Total Loadings to the Bow River, Elbow River, Fish Creek, Nose Creek and West Nose Creek which shall be established by the Director of Air and Water Approvals in consultation with the City of Calgary on or before January 1, 2003."

where "*Drainage System*" is defined as the wastewater system, storm drainage system and snow storage sites.

"*Total Loading*" is defined as the annual weight of Carbonaceous Biochemical Oxygen Demand (CBOD)[5], Total Suspended Solids (TSS)[6], Total Phosphorus[7], and Ammonia-Nitrogen[8] discharged from the drainage system to the receiving stream.

---

[5] BOD is a measure of the oxygen required by bacteria under standard conditions, to oxidize organic materials to carbon dioxide and water. If nitrogenous material is present, BOD should be separated into carbonaceous BOD and nitrogenous BOD. Carbonaceous BOD is the oxygen demand associated with organic material.

[6] Total Solids (TS) is the material residue left after evaporation and subsequent drying of a water sample. Total Suspended Solids (TSS) is the portion of the total solids retained by a filter. Total Dissolved Solids (TDS), the other component of Total Solids, is the portion that passes through the filter. TS=TSS+TDS

[7] Total Phosphorus is the total of particulate and dissolved phosphorus. Each of these may be further categorized as reactive, acid-hydrolyzable, and organic phosphorus.

[8] Ammonia-Nitrogen is all nitrogen that exists as the ammonium ion or in the equilibrium $NH_4^+ \leftrightarrow NH_3 + H^+$. Ammonia, which is one form of nitrogen, results from the biological degradation of nitrogenous organic material.

In the interim, Wastewater & Drainage has undertaken an urban runoff water quality monitoring and assessment program on various land use areas. The results of the program will aid in the establishment of future water quality parameters.

7.5 Water Quality Modelling

7.5.1 Objective

The main objective is to meet regulatory requirements for stormwater quality, which is currently a minimum removal rate of 80% of total suspended solids (TSS) for particle sizes $\geq 75\mu m$. Refer to **Section 7.5.3.2** for information regarding particle size and fractions to be included.

Several years of data collection are often inadequate to characterize the contaminant loadings contributing to receiving waters or the effectiveness of water quality treatment facilities. As well, data collection, analysis, and monitoring programs can be costly. However, the data collected from less extensive but a more intensive-sampling program can be used to calibrate computer models that can simulate contaminant loading. There are a number of computer models available, which are described in the following section. The selection of an appropriate model and the complexity of the analysis is determined by the nature of the problem, the type of drainage system, the objective(s), and the data and budget available.

7.5.2 Urban Runoff Water Quality Models

When choosing a computer model, it is important to consider the data and model limitations. Water quality computer models are relatively complex and require experienced personnel for their application. As well, quality models tend to be less accurate than quantity models, so expectations must reflect these limitations to avoid high modelling costs that do not yield the anticipated results. The following points should be kept in mind for water quality modelling:

- Modelling efforts should be kept as simple as possible. When detailed modelling is planned, coarse screening models should still be used to determine whether the detailed simulation will yield useful results.
- Lumped catchment modelling is advised, as the quality of the available runoff and contaminant loading data normally limits the accuracy of the modelling.
- Continuous simulation is required. The rate of contamination buildup and antecedent moisture conditions have a major effect on loadings.
- Selected design storms may be of use for testing treatment facility design and the impact on receiving waters once continuous simulation has been conducted.

- Calibration procedures should establish a good match of runoff volumes and peaks through single event models. Calibration of contamination buildup and washoff can be undertaken with a continuous simulation model.
- It is generally advisable to limit contaminant simulation to a few parameters such as TSS, TDS (Total Dissolved Solids), BOD, and TN.

Studies that model in-stream impacts and contaminant transport are considerably more complex and require careful planning and execution.

There are currently three computer models that Wastewater & Drainage has approved for **stormwater quality simulation**. They are as follows:

7.5.2.1 SWMM

SWMM, Stormwater Management Model, was developed by the United States Environmental Protection Agency (USEPA) in 1969-1971. It has been continually maintained and updated, and is perhaps the best known and widely used of the available urban runoff quantity and quality models in North America; it is also one of the most comprehensive modelling programs available for urban drainage analysis. SWMM is a dynamic model that is capable of simulating nonpoint source runoff quality and routing, as well as storage, treatment and other BMPs. The model can simulate a wide range of pollutants and is capable of both continuous and single event simulations. Version 4.3 and later versions are more complex in the characterization of washoff processes and stormwater runoff systems.

SWMM is composed of several blocks that can be linked together. There are four computational blocks: Runoff, Transport, Extran, and Storage/Treatment. There are also several service blocks which can be utilized: Graph, Combine, Rain, Temp and Statistics. Output from the model includes hydrographs and pollutographs.

7.5.2.2 QUALHYMO

QUALHYMO is a planning level model that simulates water quality and quantity. The model was developed in 1983 at the University of Ottawa with a grant funded by the Ontario Ministry of Environment. The model was originally designed to be a simple seasonal continuous water quality/quantity simulation model for lumped applications in urbanizing Ontario river basins. The intent was to supplement existing models with a flexible and economical model that had a reasonable scope of simulation. The model is capable of both continuous and single event simulations.

The basic structure of QUALHYMO is based on the HYMO and OTTHYMO models. A number of alternate commands were incorporated to expand the scope of the model. Some of these commands include GENERATE, POND, POLLUTANT RATES, CALIBRATE and EXCEEDANCE CURVES. These commands make QUALHYMO distinct in its ability to simulate the generation and routing of pollutants, snowmelt, simplified soil freeze-thaw and instream erosion potential. QUALHYMO is one of the simpler and less costly simulation models available.

7.5.2.3 QHM

QHM is a Windows-based watershed quantity and quality simulation model that is intended for watershed management and stormwater design. QHM was derived from the QUALHYMO model and therefore has similar features to QUALHYMO. QHM is capable of simulating rainfall-runoff, soil and groundwater effects on baseflow, evapo-transpiration, soil freeze-thaw, snowmelt and snow removal/disposal, soil erosion and urban runoff quality (pollutants). Although QHM is primarily used for continuous simulation, single event simulation is also possible.

7.5.2.4 Others

Other computer models are available such as STORM and receiving stream water quality models (HSPF, QUAL2E-U and WASP5). Refer to Alberta Environmental Protection's "Stormwater Management Guidelines for the Province of Alberta" (1999) for more information. SWMM (and XP-SWMM), QUALHYMO, and QHM are the models recommended for simulating urban runoff water quality, and in particular, sediment removal. However, computer modelling technology is evolving and new models may become available. Contact Wastewater & Drainage for approval of computer models not listed.

7.5.3 Modelling Criteria

7.5.3.1 Continuous Simulation

Continuous simulation is required to model urban runoff water quality from all wet ponds and wetlands to estimate overall sediment removal rates (TSS). It is important that reasonable input parameters be used in the simulation. Currently, little calibration information is available to verify the accuracy of the parameters. Wastewater & Drainage is currently undertaking a calibration and pollutant loading study that will provide more information on modelling parameters and sensitivity. The study is for two years (2001 and 2002); results will be made available at the conclusion of the study.

7.5.3.2 Particle Sizes and Settling Velocities

It is necessary to consider the particle size distribution for soils and their settling velocities. Although the relative distribution of the particles is seasonal, and dependent on location, a general distribution should be used for modelling purposes.

To estimate the total suspended solids removal rate from wet ponds and wetlands, Table 7.2 should be used as input into the model. **The settling velocities highlighted in the last column(2) should be used.** Settling velocities from this column were interpolated using information from the "Stormwater Management Practices Planning and Design Manual" prepared by the Ontario Ministry of Environment (1994).

Table 7.2: Particle Size and Settling Velocities for Sediment Removal

Sediment Fraction	Size (μm)	Size Fractions	Settling Velocity(1) (m/s)	Settling Velocity(2) (m/s)
1	<5	2.8%	0.000013	0.0000007
2	5-10	1.2%	0.00005	0.0000025
3	10-20	1.2%	0.00035	0.000008
4	20-75	5.8%	0.0013	0.000025
5	>75	89%	0.005	0.0005
Total		**100%**		

(1) Settling velocities from "*Strathcona Development Area Sediment Control Analysis*", J. N. MacKenzie Engineering Ltd., 1990

(2) Effective settling velocities interpolated from "*Stormwater Management Practices Planning and Design Manual*", Ontario Ministry of Environment and Energy, 1994

Settling velocities from the second last column(1) are provided for reference only and pertain to information obtained by a study undertaken by J.N. MacKenzie Engineering Ltd. in 1990. This study was based on street sweeping samples; however, this may underestimate the amount of smaller particles in the runoff. The Ontario Ministry of Environment results provide a better range of particle sizes and should be used in the interim. Wastewater & Drainage will determine more appropriate particle distributions and settling velocities as part of the calibration and pollutant loading study.

7.5.3.3 Rate of Sediment Accumulation

The rate of sediment accumulation can also be modelled to establish an approximate sediment removal schedule. If the forebay of the pond is to be used for erosion control during development of the area, then the frequency of cleaning will have to be escalated. See **Section 10.2.2.11** for frequency of cleaning recommendations.

7.5.3.4 Technical Requirements

A technical stormwater report is required indicating the following water quality information:

- Model used
- Input parameters
- Input and Output computer files
- Proposed Water Quality Monitoring Program
- Results (sediment removal rate, rate of accumulation, frequency of cleaning, size and volume of pond required to meet water quality requirements)

For further report requirements see **Section 11.0 Technical Requirements**.

7.6 Pond Sizing

Stormwater ponds, in particular wet ponds and wetlands, must provide an active storage volume (above NWL) for a 100 year return period storm. However, the ponds must also be sized to provide a minimum 80% removal of Total Suspended Solids (TSS) for particle sizes $\geq 75\mu m$ for water quality. The more conservative volume of the two criteria shall dominate. As well, a minimum volume equal to 25 mm over the entire catchment area (25 mm x area) is required for both the permanent pool and active storage for water quality requirements for wet ponds. A minimum detention time of 24 hours must also be provided. Refer to **Sections 6.3** and **6.4** for additional information on pond sizing requirements.

Release rates from the ponds must conform to the rates set out in the approved Master Drainage Plan report and/or approved Staged Master Drainage Plan report.

When future pollutant loading regulations are implemented, storage capacity must meet these new regulations.

7.7 Cold Climate Impacts

Most stormwater treatment ponds are negatively affected by the winter season. Smaller ponds will tend to freeze, and any vegetation in the ponds will be relatively ineffective during this period of time. The effectiveness of other BMPs, such as pervious pipe systems, grassed swales and soakaway pits, etc., will likely be reduced also. However, some BMPs are less affected by winter conditions. The effects of chinooks are even less understood; more research is required in this area.

The reduction in water quality performance during the winter period has not been regarded as significant in the past since runoff volumes are much less. Larger volumes in the spring due to snowmelt help dilute the pollutants, reducing concerns of instream habitat degradation.

An extensive review of cold climate design considerations was recently undertaken by the Center for Watershed Protection (Stormwater BMP Design Supplement for Cold Climates, 1997). Recommendations include:

- Increasing storage volumes to account for volume reductions due to ice and the effects of spring melt
- Sizing and locating inlets and outlets to avoid ice clogging and freeze-up
- Prohibiting early spring drawdown for maintenance to avoid discharge of anoxic or high chloride concentrated water

Use of these recommendations is encouraged.

7.8 Water Quality Monitoring Program

Water quality monitoring is required for all wet ponds and wetlands during the maintenance period. Costs of the program are to be covered by the developer during this time period. Contact the Water Quality Engineer in Wastewater & Drainage for further information and details; changes to the program are controlled by the Water Quality Engineer.

The analysis of urban runoff quality can be a valuable tool for assessing the effectiveness of treatment ponds and BMP design, and to serve as a tool for determining any corrective steps required to effectively manage these facilities. The water quality monitoring program should include the following:

Sampling Locations

Both the inlet and outlet should be sampled.

Sampling Frequency

i. A monthly grab sample is required to determine a baseline. This includes the winter months also.
ii. Five (5) storm events per summer season must be sampled.
iii. Two (2) chinook/snowmelt events per season (winter/spring) must be sampled.

Parameter Analysis

All samples should be analyzed for the following parameters:

Metals (mg/l)
- Aluminum (Al)
- Cadmium (Cd)
- Chromium (Cr)
- Copper (Cu)
- Iron (Fe)
- Nickel (Ni)
- Lead (Pb)
- Zinc (Zn)

Nutrients and Others (mg/l)
- Total Suspended Solids (TSS)
- Total Dissolved Solids (TDS)
- Biochemical Oxygen Demand (BOD)*
- Chemical Oxygen Demand (COD)
- Total Kjeldahl Nitrogen (TKN)
- Ammonia-Nitrogen (NH_3-N)
- Nitrate (NO_3)
- Nitrite (NO_2)
- Total Phosphorus (TP)
- Dissolved Reactive Phosphorus (TDP)*
- Ortho-Phosphate*
- pH
- Dissolved Oxygen (DO)*
- Conductivity
- Turbidity

Major Ions
- Sodium (Na^{2+})*
- Potassium (K^+)*
- Magnesium (Mg^{3+})*
- Calcium (Ca^{2+})*
- Chloride (Cl^-)*
- Sulfate (SO_4^-)*

Microbiological
- Total Coliform*
- Fecal Coliform*
- Fecal Streptococcus*
- E.Coli*

* Parameters analyzed only in baseflow samples
NOTE: Monitoring parameters are subject to change

A monitoring report is to be prepared annually and submitted to the Water Quality Engineer in Wastewater & Drainage. Contact the Water Quality Engineer for further information.

8.0 Best Management Practices

8.1 Introduction

Best Management Practices, or BMPs, are activities or practices, or a combination of practices, that are designed to prevent or reduce the release of pollutants to receiving waters or streams. BMPs operate by trapping stormwater runoff and detaining it until unwanted pollutants such as sediment, phosphorous and other harmful contaminants are allowed to settle out or be filtered through underlying soils. The trapped pollutants are then removed through periodic maintenance. Stormwater pollutants can be harmful to the aquatic environment (see **Section 7.0 Water Quality**).

Most annual urban runoff quantities are the result of more common smaller storms. However, the large storms tend to be the focus of most drainage design because they represent the most significant conveyance problems. In terms of water quality, it is the smaller more frequent storms that represent the largest pollutant loading problems to the receiving water bodies. This is due to the "first flush" runoff that generally contains the most contaminants. By capturing and treating the first flush runoff, significant reductions can be made in pollutant release.

The selection and design of stormwater BMPs must incorporate both water quantity and water quality concerns. Current stormwater quality criteria for the City of Calgary requires the removal of a minimum of 80% total suspended solids (TSS) for particle sizes ≥75μm. By 2003, pollutant loading criteria will be established that will identify additional pollutant controls. Although not all BMPs may be able to meet this criteria, they do go a long way in reducing pollutant runoff.

Care should be made in selecting the appropriate BMP or combination of BMPs. Overall education is an integral component of successful design and implementation. It is the designer/consultant's responsibility to ensure that all BMPs are properly designed according to site conditions or constraints, and that details are provided on the drawings. **All BMPs require the approval of Wastewater & Drainage.**

Good planning and design integrates the design of a site and stormwater management facilities. The integration of BMPs into the planning and design process is essential for an effective stormwater management plan. Although site-specific conditions or characteristics will govern the stormwater management solutions used to some extent, the designer must use his/her own experience and judgement, and the requirements of the municipality, to successfully use and design stormwater controls.

There are many types or classifications of BMPs that can be implemented to reduce stormwater pollutants. The following information details the most common BMPs used, but by no means is the complete list. As well, some BMPs may be better suited to Calgary's climate and conditions than others. These limitations should be recognized. The BMPs chosen for Calgary are based on the following classifications:

- source control
- lot-level
- conveyance
- treatment, and
- pre-treatment

BMPs can also be further classified in terms of structural or non-structural BMPs. These terms and classifications are described further on. For more information, also refer to Alberta Environmental Protection's "Stormwater Management Guidelines for the Province of Alberta" (1999) or "Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage System" (1997).

8.2 Source Control BMPs

The impacts of stormwater pollutants can often be mitigated through the use of source control BMPs to remove stormwater contaminants at their source. Where possible, stormwater should be prevented from running onto surfaces where pollutants can be picked up. When contaminants are picked up, they should be routed to treatment BMPs.

There are several opportunities to implement source control BMPs. However, to implement a successful source control program, it is essential to include those who are part of the problem or are affected by the pollution, to develop a sense of ownership. By developing a sense of ownership of the problem, those that are affected can be made aware of the problem, the consequences and implications, and how to reduce the problem. The most effective programs should include public and private sector awareness and education regarding household, recreational and work activities. Education should include information about alternative practices and ways to reduce pollutants. Opportunities to promote education can include partnering with groups such as the Bow River Basin Council and River Valleys Committee. Developers can also help promote source controls by educating home builders and home owners where possible.

Source control BMPs can include a number of activities such as restricting pesticide and fertilizer use, following good housekeeping practices, controlling construction activities, street sweeping, catchbasin cleaning, and animal waste removal to name a few. Refer to **Appendix G** for additional information.

8.2.1 Pesticide and Fertilizer Use

Pesticide and fertilizer use is associated with a wide range of activities, including households, businesses, and governmental agencies. Pesticide use can be controlled by the amount and timing of the application, and use of alternatives. The use of pesticides can be minimized through Integrated Pest Management (IPM), which promotes:

- use of natural predators and pathogens

- mechanical removal of weeds, eggs, larvae and insects
- changing habitat to minimize pest insect breeding
- timing applications to the most vulnerable phase of the pest's life cycle
- concentrating efforts on the most widely affected areas
- using site-specific methods, and
- using degradable and non-carcinogenic pesticides

The City of Park Development & Operations has developed and implemented its own Integrated Pest Management plan; this IPM plan has been in effect since 1998.

Chemical fertilizers are a significant source of nutrients (mainly phosphorous and nitrogen) in urban runoff. However, the use of fertilizers can be minimized by controlling the amount and timing of the application, and through use of other alternatives. Other practices should include:

- limiting application of fertilizers
- incorporating fertilizers directly into the soil (avoid surface applications)
- usage of slow-release fertilizers
- substituting compost and peat for chemicals
- confining applications to seasonal periods that minimize losses to surface and ground waters
- avoiding applications during extended dry periods, and
- avoiding excessive watering of lawns

8.2.2 Good Housekeeping

General good housekeeping practices are also beneficial to providing source control. These practices can be applied to household, commercial, industrial and construction activities:

- Promptly contain and clean up solid and liquid pollutant leaks and spills, including oils, solvents, fuels, and dust from manufacturing operations. Absorbent materials such as clay and peat can be used where practicable.
- Do not hose down or discharge pollutants to storm drains, conveyance ditches or receiving waters.
- Promptly repair or replace all leaking connections, pipes, hoses, valves, etc. that can contaminate stormwater.
- Sweep handling and storage areas on a regular basis and if needed, dispose of dust and debris that could contaminate stormwater.
- Recycle materials such as oils, solvents, coolants, waste, etc. as much as possible.
- Cover and contain materials, equipment, waste, and compost piles

that could cause leachate contamination of stormwater.

- Use drip pans to collect leaks and spills from industrial/commercial equipment, or repair equipment.
- Use environmentally safer raw materials, products, additives, etc.

8.2.3 Household, Industrial and Commercial Activities

Household activities can be altered to reduce stormwater contamination. This includes controlling use of hazardous products or using non-hazardous products, preventing disposal of hazardous materials into storm sewers, reducing fertilizer and pesticide use, and management of pet, kitchen and yard wastes. Public education of householders is the key component to controlling source pollution. Homeowners must be made aware of the consequences of polluting stormwater runoff, and how they can help mitigate these impacts. Driveways and sidewalks should be swept, not hosed, to avoid oil and grease from washing into the storm sewer. Fluid leaks from vehicles and equipment should be repaired, and spills absorbed with the appropriate absorbent material. Hazardous wastes should be collected and dropped off at facilities or depots that handle these types of waste.

Industrial and commercial activities can generate significant metal and organic contaminants. Manufacturing and disposal practices can be changed to promote the recycle and reuse of materials that cause pollution. Generated pollutants that cannot be altered or changed should be enclosed or covered. Any resulting contaminated runoff should then be treated on-site or routed to the sanitary sewer, if permitted. Spill prevention and control plans should be in place, and staff should have proper training and education. See **Appendix G** for further information.

8.2.4 Automobile-related Activities

Automobile-related activities can generate a wide range of pollutants, in particular metals and hydrocarbons. This includes the wear and corrosion of parts, and leaking and disposal of oils and lubricants. Some source control measures that can be implemented include:

- using unleaded gasoline
- cleaning heavily used parking and commercial lots
- using oil and grease recycling centres
- inspecting and repairing vehicle fluid leaks
- reduce vehicle use

As well, roadway de-icing during the weather also contributes to heavy metal, cyanide, and high salt concentrations in runoff. High salt concentrations can also exert stress on roadside vegetation and in receiving waters. By reducing the use of de-icing salt, using alternative de-icers, or substituting sand and gravel for salt, the impact of de-icer pollutants can be minimized. Unfortunately, there is no practical method of roadway de-icing that is completely environmentally satisfactory.

8.2.5 Construction Activities

Soil erosion caused by construction activities has been identified as a primary source of suspended solids in urban runoff. As well, construction activities generate pollutants from pesticides, petroleum products (fuels and lubricants), nutrients (mainly from fertilizers used in revegetation), solid waste (trees, shrubs, wood, paper, scrap metals), garbage (food wrappings, cigarette packages and butts, etc.), construction chemicals (paints, cleaners, etc.), and other pollutants such as concrete wash water.

Source controls such as the frequent collection and disposal of petroleum wastes, cleaning materials, and site debris/garbage are effective in minimizing pollutant transport. Erosion and sediment controls must be implemented to control soil erosion and to retain eroded soils on-site. Refer to **Section 9.0** for information on erosion and sediment controls. Temporary sedimentation controls, such as sedimentation ponds, will aid in pollutant control. Erosion and sediment controls should always be developed as an integral part of the planning process. Water quality should be monitored before, during and after construction activities to determine the effectiveness of mitigation techniques. See **Appendix G** for further information.

8.2.6 Street Sweeping

Street sweeping removes a portion of the pollutants deposited on roads and parking lot surfaces, thereby reducing pollutant runoff to storm sewers and receiving waters. However, the effectiveness of street sweeping is dependent on the time of year, frequency, length of time between rainfall events, type of sweeping equipment (vacuum, wet, dry etc.), and the type of road surface. Early spring is typically the most effective time to remove accumulated winter pollutants.

To significantly reduce pollutant loadings, street sweeping must be carried out very frequently (daily). Based on studies done by the Ontario Ministry of Environment and Energy (MOEE), street sweeping programs undertaken once or twice per month remove less than 5% of pollutant loadings. However, one advantage of street sweeping is the control of street solids and their associated pollutants.

8.2.7 Catchbasin Cleaning

Catchbasins, with and without sumps, can collect debris and sediment. The cleaning of accumulated sediments in catchbasins can reduce the amount of pollutants discharged to receiving waters. While catchbasins with sumps are more effective in trapping the larger runoff particles than catchbasins without sumps, fecal bacteria control is not effective.

8.2.8 Animal Waste Removal

Fecal bacteria in animal waste is a significant pollutant source. By prohibiting littering and controlling disposal of animal wastes, a portion of the pollutants deposited on the ground surface can be reduced, and thereby reduce pollutant contamination of stormwater. Public education is essential to raise public awareness.

8.3 Lot-Level BMPs

Lot-level BMPs, or controls, are practices that reduce runoff volumes and/or treat stormwater before it reaches a conveyance system. The controls are applied at the individual lot level or on multiple lots that drain a small area (<2 ha). When determining the suitability of lot-level controls, the site constraints should be carefully considered.

8.3.1 Reduced Lot Grading

Reducing lot grades will reduce the volume of runoff from developed lots by increasing runoff travel time, depression storage, and infiltration. In Calgary, the local building code requires a minimum lot grade of 10% to drain stormwater away from buildings. However, in flat areas with well-compacted material, a reduction in lot grades to 2% could be evaluated.

Very little information is available regarding the impact of lot grading reductions on runoff volumes. The practice is intended to promote recharge and reduce downstream erosion potential.

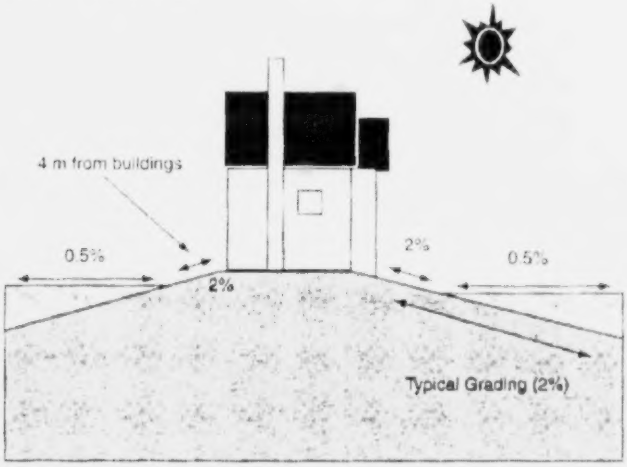


Figure 8.1: Lot Grading Guidelines

more effective in trapping the larger runoff particles than catchbasins without sumps, fecal bacteria control is not effective.

8.2.8 Animal Waste Removal

Fecal bacteria in animal waste is a significant pollutant source. By prohibiting littering and controlling disposal of animal wastes, a portion of the pollutants deposited on the ground surface can be reduced, and thereby reduce pollutant contamination of stormwater. Public education is essential to raise public awareness.

8.3 Lot-Level BMPs

Lot-level BMPs, or controls, are practices that reduce runoff volumes and/or treat stormwater before it reaches a conveyance system. The controls are applied at the individual lot level or on multiple lots that drain a small area (<2 ha). When determining the suitability of lot-level controls, the site constraints should be carefully considered.

8.3.1 Reduced Lot Grading

Reducing lot grades will reduce the volume of runoff from developed lots by increasing runoff travel time, depression storage, and infiltration. In Calgary, the local building code requires a minimum lot grade of 10% to drain stormwater away from buildings. However, in flat areas with well-compacted material, a reduction in lot grades to 2% could be evaluated.

Very little information is available regarding the impact of lot grading reductions on runoff volumes. The practice is intended to promote recharge and reduce downstream erosion potential.

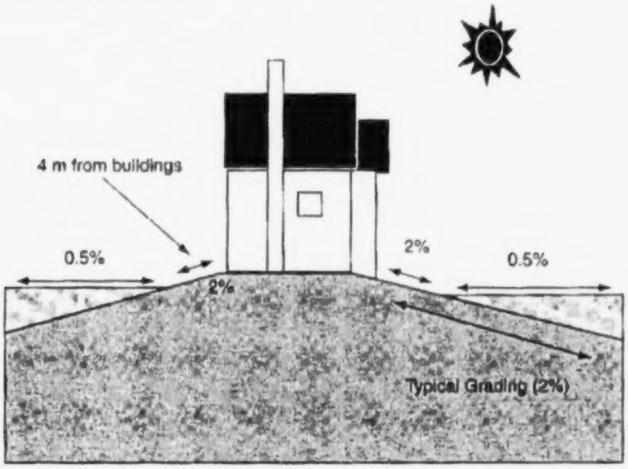


Figure 8.1: Lot Grading Guidelines

Design Considerations

- To avoid foundation drainage problems, a 2% minimum grade should be maintained within 2 to 4 m of buildings; soils in this zone should be well-compacted. Outside this envelope, the grading can be flattened to 0.5% to promote greater depression storage and natural infiltration.
- Roof leaders should extend 2 m away from the building.
- Infiltration can be improved by tilling.
- Reduced lot grading can be implemented for soil types with a minimum infiltration rate of 15 mm/hr or greater. This generally includes soils coarser than loam. Clay soils are not suitable.

8.3.2 Surface Ponding and Roof Top Storage

Roof leaders that discharge to surface ponding areas help reduce downstream flooding and erosion. Rooftop storage, which is suitable for commercial, industrial and institutional sites, provides similar benefits. However, water quality benefits of both are limited.

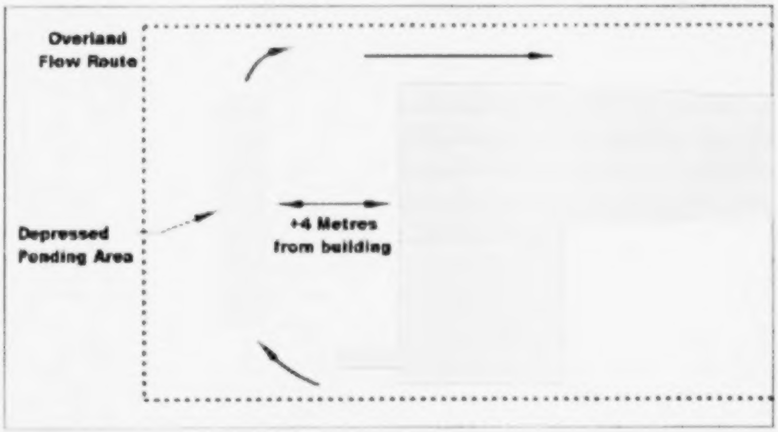


Figure 8.2: Rear Yard Ponding

Ponding areas can be created in rear yards (see Figure 8.2); roof leaders are then directed towards the depressions to allow stormwater to infiltrate or evaporate. Surface ponding can also be used for parking lots or park areas. For rooftop storage, drains on flat roofs are raised to allow ponding on the rooftop.

Design Considerations

- Ponding areas on residential lots should have a depression no deeper than

100 mm. Overland escape routes need to be established for depths greater than this.

- Ponding areas should be located a minimum of 4 m away from building foundations.
- More complex designs may incorporate an infiltration trench beneath the ponding area to enhance infiltration.
- Rear ponding areas should be sized to accommodate a volume equal to a minimum of 5 mm to a maximum of 20 mm of rainfall over the roof area.
- Infiltration can be improved by tilling.
- Rear lot ponding can be implemented for soil types with a minimum infiltration rate of 15 mm/hr or greater. This generally includes soils coarser than loam. Clay soils are not suitable.
- For commercial and industrial rooftop storage, a maximum depth of 10 mm should be allowed before water can flow through the roof hoppers. Roof supports must be adequate to support the weight of the ponded water.

8.3.3 On-Lot Infiltration Systems

On-lot infiltration systems are used for stormwater detention from relatively small drainage areas. They provide some reduction in overland flows and enhancement of water quality. On-lot infiltration systems may be simply designed pits with a filter liner and rock drain material or more complex systems with catchbasin sumps and inspection wells (see Figures 8.3 and 8.4). Stormwater from roof drains is directed to the infiltration system.

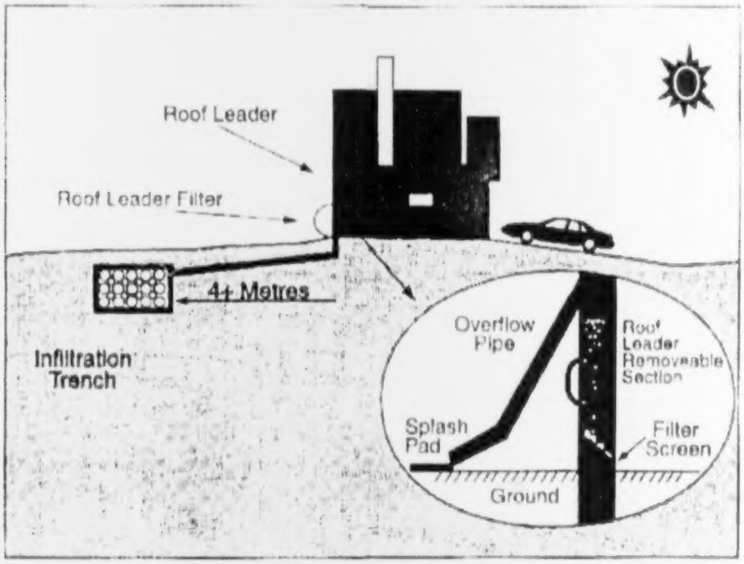


Figure 8.3: Infiltration System with Roof Leader Filter (Soakaway Pit)

100 mm. Overland escape routes need to be established for depths greater than this.

- Ponding areas should be located a minimum of 4 m away from building foundations.
- More complex designs may incorporate an infiltration trench beneath the ponding area to enhance infiltration.
- Rear ponding areas should be sized to accommodate a volume equal to a minimum of 5 mm to a maximum of 20 mm of rainfall over the roof area.
- Infiltration can be improved by tilling.
- Rear lot ponding can be implemented for soil types with a minimum infiltration rate of 15 mm/hr or greater. This generally includes soils coarser than loam. Clay soils are not suitable.
- For commercial and industrial rooftop storage, a maximum depth of 10 mm should be allowed before water can flow through the roof hoppers. Roof supports must be adequate to support the weight of the ponded water.

8.3.3 On-Lot Infiltration Systems

On-lot infiltration systems are used for stormwater detention from relatively small drainage areas. They provide some reduction in overland flows and enhancement of water quality. On-lot infiltration systems may be simply designed pits with a filter liner and rock drain material or more complex systems with catchbasin sumps and inspection wells (see Figures 8.3 and 8.4). Stormwater from roof drains is directed to the infiltration system.

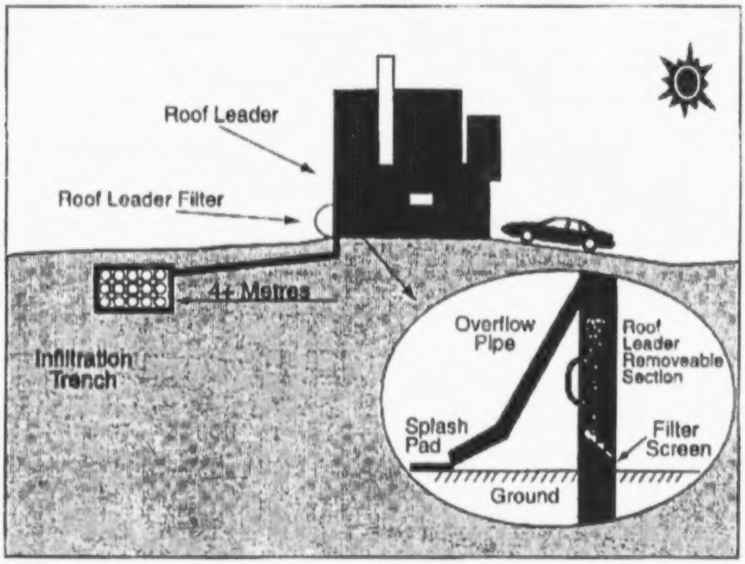


Figure 8.3: Infiltration System with Roof Leader Filter (Soakaway Pit)

The simply designed pits are commonly called soakaway pits and often serve a single lot.

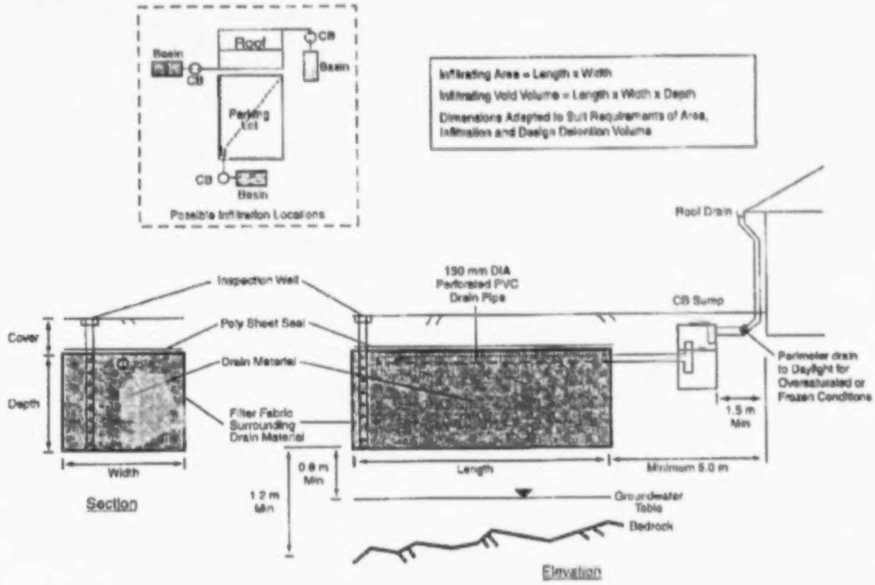

Roof
CB
Basin
Basin
CB
Parking Lot
CB
Basin
Possible Infiltration Locations
Infiltrating Area = Length x Width
Infiltrating Void Volume = Length x Width x Depth
Dimensions Adapted to Suit Requirements of Area, Infiltration and Design Detention Volume
Roof Drain
Inspection Well
150 mm DIA Perforated PVC Drain Pipe
CB Sump
Poly Sheet Seal
Cover
Drain Material
Depth
Perimeter drain to Daylight for Oversaturated or Frozen Conditions
Filter Fabric Surrounding Drain Material
1.5 m Min
Width
0.6 m Min
Length
Minimum 5.0 m
Section
1.2 m Min
Groundwater Table
Bedrock
Elevation

Figure 8.4: Infiltration System with Pre-treatment Sump

Design Considerations

- The distance between the bottom of the pit to the water table should be ≥ 0.6 m. As well, the distance between the bottom of the pit and bedrock should be ≥ 1.2 m.
- The trench should be located at least 4 m away from the foundation of the nearest building.
- The trench should be comprised of clean 50 mm diameter stone and lined with suitable geotextile.
- The total void volume of the trench should be based on the storage required for the 2 year design storm, based on the effective porosity of the trench media. The required infiltration surface area (bottom surface area) to drain the system within 48 hours is calculated from the 24 hour sustained percolation rate.
- The trench should be located close to the ground surface, but factors such as the depth of trench storage, frost heave potential, and surrounding soil stratification should be considered.
- A filter should be incorporated into the soakaway pit design (Figure 8.3) or the sump (Figure 8.4) to limit solids and debris into the system. An overflow pipe should be included where possible.
- On-lot infiltration systems should not be constructed on fill material, under parking lots, or under multi-use areas.

- On-lot infiltration systems can be implemented for soil types with a minimum infiltration rate of 15 mm/hr or greater. This generally includes soils coarser than loam. Clay soils are not suitable.

8.3.4 Sump Pumping of Foundation/Weeping Tile Drains

City of Calgary standards permit the direct connection of foundation (or weeping tile) drains to the storm sewer. However, there are situations where this may not always be possible or practicable (ie. high hydraulic grade line, no access to storm sewer connection, etc.). For these situations, foundation drainage can be pumped to the surface or to a suitable infiltration system. Sump pumping helps alleviate flooding and erosion concerns. Foundation drainage is usually relatively clean water; if this water is removed from the sewer network, there will be some impact on the dilution of pollutants that was provided by the foundation drainage.

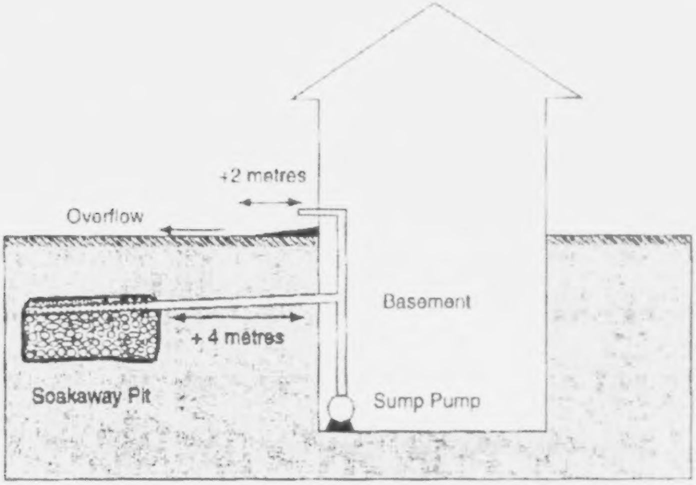


Figure 8.5: Sump Pump Foundation Drainage

Design Considerations

- The discharge point should be located at least 2 m away from the foundation.
- There should be sufficient grading away from the foundation wall when the sump pump discharge is to the ground surface, to convey drainage away from the building.
- Sump pumps that discharge to the surface should discharge at least 0.5 m above the ground to prevent blockage from ice and snow during the winter.
- Design of the soakaway pit should follow the design considerations listed in **Section 8.3.3**.

- On-lot infiltration systems can be implemented for soil types with a minimum infiltration rate of 15 mm/hr or greater. This generally includes soils coarser than loam. Clay soils are not suitable.

8.3.4 Sump Pumping of Foundation/Weeping Tile Drains

City of Calgary standards permit the direct connection of foundation (or weeping tile) drains to the storm sewer. However, there are situations where this may not always be possible or practicable (ie. high hydraulic grade line, no access to storm sewer connection, etc.). For these situations, foundation drainage can be pumped to the surface or to a suitable infiltration system. Sump pumping helps alleviate flooding and erosion concerns. Foundation drainage is usually relatively clean water; if this water is removed from the sewer network, there will be some impact on the dilution of pollutants that was provided by the foundation drainage.

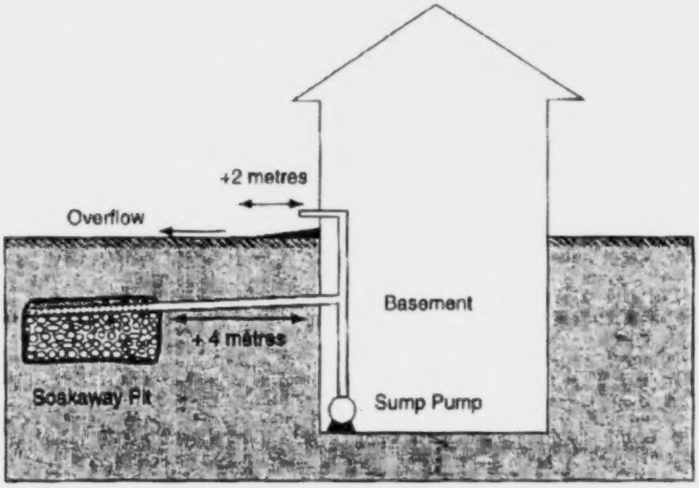


Figure 8.5: Sump Pump Foundation Drainage

Design Considerations

- The discharge point should be located at least 2 m away from the foundation.
- There should be sufficient grading away from the foundation wall when the sump pump discharge is to the ground surface, to convey drainage away from the building.
- Sump pumps that discharge to the surface should discharge at least 0.5 m above the ground to prevent blockage from ice and snow during the winter.
- Design of the soakaway pit should follow the design considerations listed in **Section 8.3.3**.

8.3.5 Superpipe Storage

Superpipes can be used to reduce peak flow rates by providing sub-surface storage. Pre-manufactured pipe is typically used for the installation. The outflow rates must be controlled to ensure runoff is detained in the superpipe. In general, superpipes are utilized for small catchment areas and little water quality enhancement is achievable. Installation locations include parking lots, grassed swales, and adjacent to property boundaries.

Design Considerations

- Inlets and outlets must be sized to control specified outflow rates. The length and diameter of the superpipe will be a function of the storage required.
- A minimum slope of 0.5% is recommended to facilitate drainage of the pipe. However, slopes should be kept to a minimum; steep slopes will reduce the amount of storage within the pipe.
- Access points are required for cleaning purposes.
- Surface overflow paths (emergency escape routes) should be included in the event of the outlet plugging.

8.3.6 Infiltration Trenches

The purpose of an infiltration trench is to collect and provide temporary storage of surface runoff and to promote infiltration. Infiltration trenches can be constructed at ground surface to intercept overland flows directly, or they can be constructed underground (subsurface) as part of a storm sewer system. See Figures 8.6 and 8.7. In general, infiltration trenches are composed of a clear stone storage media with a sand or peat filter layer; non-woven geotextile can also be used as a filter.

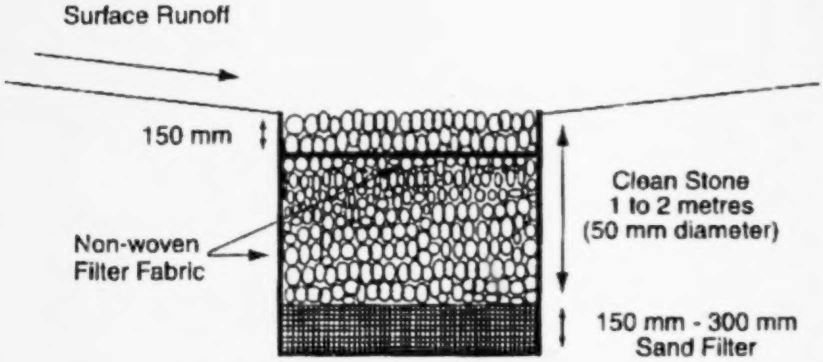

Surface Runoff
150 mm
Non-woven Filter Fabric
Clean Stone 1 to 2 metres (50 mm diameter)
150 mm - 300 mm Sand Filter

Figure 8.6: Surface Infiltration Trench

Infiltration trenches are generally implemented for small drainage areas (< 2 ha), rather than large-scale areas. Normally they are implemented for small residential areas consisting of a few lots, multi-family housing, commercial areas, parking lots and open space areas. Use of infiltration trenches for industrial land is discouraged due to the high potential for groundwater contamination; as well, some commercial parking lots may not be suitable either. Where possible, some form of upstream pre-treatment is recommended (ie. filter strips, oil/grit separators, etc.).

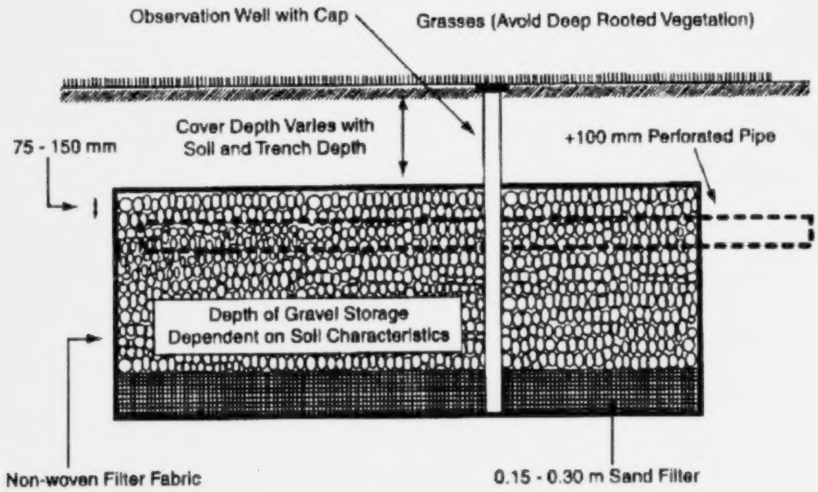

Observation Well with Cap
Grasses (Avoid Deep Rooted Vegetation)
75 - 150 mm
Cover Depth Varies with Soil and Trench Depth
+100 mm Perforated Pipe
Depth of Gravel Storage Dependent on Soil Characteristics
Non-woven Filter Fabric
0.15 - 0.30 m Sand Filter

Figure 8.7: Subsurface Infiltration Trench

Infiltration trenches are effective in managing runoff from small areas. Although infiltration trenches provide only marginal water quantity control, on-lot runoff volumes are reduced, thereby reducing end-of-pipe storage requirements. Infiltration of the stormwater will also provide recharge to the groundwater. Infiltration trenches also enhance water quality. However, clogging of the filter material can be a frequent problem if sediment content is high or if pre-treatment BMPs are not used.

Design Considerations

- Infiltration trenches should include a pre-treatment system for solids removal to prevent frequent clogging.
- Infiltration trenches can be implemented for soil types with a minimum infiltration rate of 15 mm/hr or greater. This generally includes soils coarser than loam. Clay soils are not suitable.
- Infiltration trenches should not be installed in areas with seasonally high water tables. This system should not be implemented where the water table is within 1 m of the bottom of the infiltration trench.

- The depth to bedrock should be ≥ 1 m below the bottom of the infiltration trench to ensure adequate drainage.
- Careful consideration should be given to the volume of stormwater directed to the trench. The volume of the trench should be sufficient to allow drainage within 48 hours maximum.
- The storage media should consist of clear 50 mm diameter stone to promote filtration with a low clogging frequency.
- A non-woven geotextile should be used at the interface between the pipe bedding and the native soil to prevent native soil from clogging the voids in the storage media. If a subsurface infiltration trench is used, the filter fabric should extend to the cover the top of the trench.
- The filter layer is generally constructed beneath the storage layer to provide tertiary treatment of the stormwater before it infiltrates into the native soil. The most common filter media used is sand, although a mixture of sand and peat can also be used.

8.4 Conveyance System BMPs

Stormwater conveyance system BMPs transport runoff from developed areas through sewers or grassed swale systems.

8.4.1 Pervious Pipe Systems

Pervious pipe systems are intended to convey and infiltrate stormwater runoff. Although these systems have not been commonly used, some municipalities in Ontario have implemented them. However, these systems are still experimental and are being monitored.

Pervious pipe systems consist of a perforated pipe system that allows the exfiltration of water through the pipe wall as it is conveyed downstream. The system is similar to a conventional weeping tile system. Road runoff normally carries high levels of solids, oils, greases, metals, and chlorides (if salt is applied during winter months) and contributes a substantial amount of discharge due to the high imperviousness of road surfaces. Therefore, any stormwater exfiltrated through the pervious pipe system will reduce total end-of-pipe discharge and treatment requirements.

Pervious pipe systems for the exfiltration of road runoff have not proven very reliable. The primary reason for failure is clogging, which has been attributed to poor design (storage media, lack of filter cloth, lack of pre-treatment), poor construction practices, poor physical site conditions (soils, water table), and inadequate stabilization of the development prior to installation of the pipe system. Therefore, it is important that these factors be overcome to implement a successful system. It is especially important that pre-treatment be utilized. This can be achieved by conveying the runoff over grassed areas to filter sediments prior to flowing into stormwater catchbasins. Raising of the stormwater catchbasins will allow some ponding and further sediment removal.

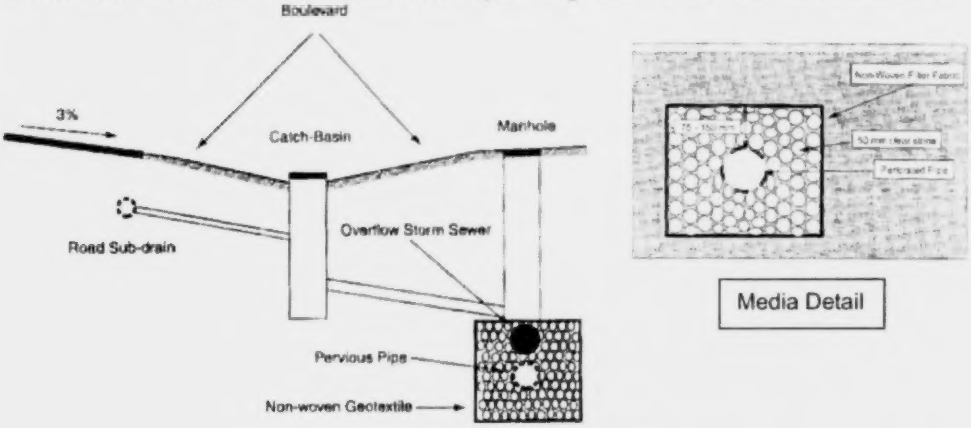


Figure 8.8: Pervious Pipe System

Design Considerations

- Pervious pipe systems should include a pre-treatment system for solids removal to prevent frequent clogging.
- Pervious pipe systems can be implemented for soil types with a minimum infiltration rate of 15 mm/hr or greater. This generally includes soils coarser than loam. Clay soils are not suitable.
- Pervious pipe systems should not be installed in areas with seasonally high water tables, otherwise groundwater will be drained and the pipe foundation may be potentially undermined. This system should not be implemented where the water table is within 1 m of the bottom of the storm sewer backfill material.
- The depth to bedrock should be ≥ 1 m below the bottom of the pervious pipe storage media to ensure adequate drainage.
- The minimum storage volume should be equal to the runoff from a 5 mm storm over the contributing area. This volume should be accommodated in the pervious pipe bedding/storage media without overflowing. The maximum storage volume should be equal to the runoff from a 25 mm storm over the contributing drainage area. The bedding should drain within 24 hours. The depth of the exfiltration storage can be calculated based on the native soil percolation rate.
- The exfiltration storage bedding depth should be 75 to 150 mm deep above the crown of the pervious pipe.
- A non-woven geotextile should be used at the interface between the pipe bedding and the native soil to prevent native soil from clogging the voids in the storage media.
- The minimum diameter for the pervious pipe should be 200 mm and the pipe

should be smooth walled to reduce the potential for clogging. The pervious pipe system should be installed with reasonably flat slopes (0.5%) to promote exfiltration.

8.4.2 Pervious Catchbasins

Pervious catchbasins are normal catchbasins with larger sumps that are physically connected to an exfiltration storage media. The storage media is typically located beneath or beside the catchbasin. Pervious catchbasins are intended to convey and infiltrate road drainage with high levels of suspended sediment. Road runoff normally carries high levels of solids, oils, greases, metals, and chlorides (if salt is applied during winter months) and contributes a substantial amount of discharge due to the high imperviousness of road surfaces. Therefore, any stormwater exfiltrated through the pervious pipe system will reduce total end-of-pipe discharge and treatment requirements.

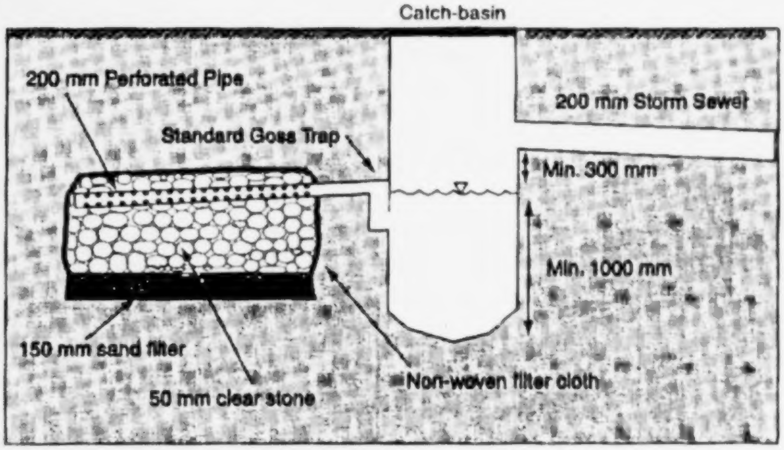


Figure 8.9: Pervious Catchbasin

Pervious catchbasins are still considered experimental and are subject to clogging problems due to poor design (storage media, lack of filter cloth, lack of pre-treatment), poor construction practices, poor physical site conditions (soils, water table), and inadequate stabilization of the development prior to installation of the pipe system. Therefore, it is important that pre-treatment be utilized. This can be achieved by conveying the runoff over grassed areas to filter sediments prior to flowing into the pervious catchbasins. The deep sumps in the pervious catchbasins will help treat the runoff before it is conveyed. Frequent cleaning of the pervious catchbasin is required to ensure longevity of the BMP.

Design Considerations

- Pervious catchbasins should include a pre-treatment system for solids should be smooth walled to reduce the potential for clogging. The pervious pipe system should be installed with reasonably flat slopes (0.5%) to promote exfiltration.

8.4.2 Pervious Catchbasins

Pervious catchbasins are normal catchbasins with larger sumps that are physically connected to an exfiltration storage media. The storage media is typically located beneath or beside the catchbasin. Pervious catchbasins are intended to convey and infiltrate road drainage with high levels of suspended sediment. Road runoff normally carries high levels of solids, oils, greases, metals, and chlorides (if salt is applied during winter months) and contributes a substantial amount of discharge due to the high imperviousness of road surfaces. Therefore, any stormwater exfiltrated through the pervious pipe system will reduce total end-of-pipe discharge and treatment requirements.

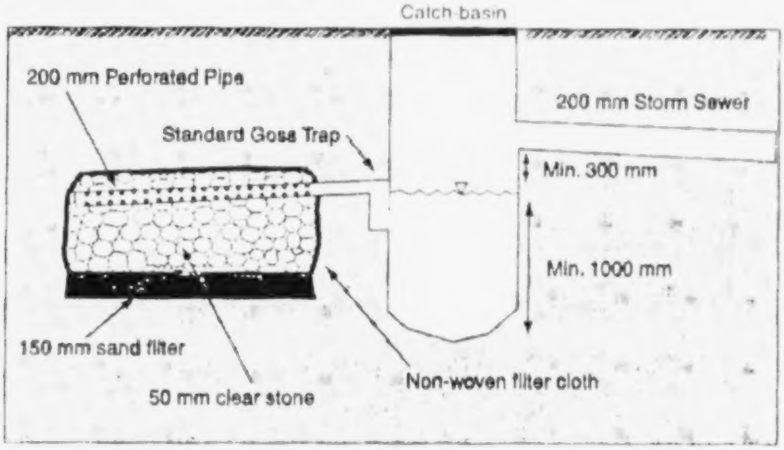


Figure 8.9: Pervious Catchbasin

Pervious catchbasins are still considered experimental and are subject to clogging problems due to poor design (storage media, lack of filter cloth, lack of pre-treatment), poor construction practices, poor physical site conditions (soils, water table), and inadequate stabilization of the development prior to installation of the pipe system. Therefore, it is important that pre-treatment be utilized. This can be achieved by conveying the runoff over grassed areas to filter sediments prior to flowing into the pervious catchbasins. The deep sumps in the pervious catchbasins will help treat the runoff before it is conveyed. Frequent cleaning of the pervious catchbasin is required to ensure longevity of the BMP.

Design Considerations

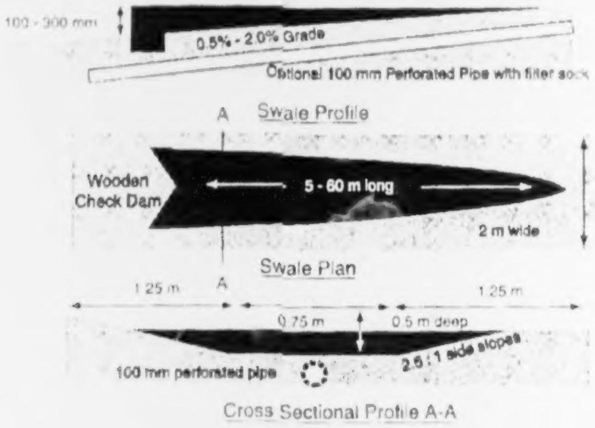
- Pervious catchbasins should include a pre-treatment system for solids removal to prevent frequent clogging.

- Pervious catchbasins can be implemented for soil types with a minimum infiltration rate of 15 mm/hr or greater. This generally includes soils coarser than loam. Clay soils are not suitable.
- Pervious catchbasins should not be installed in areas with seasonally high water tables. This system should not be implemented where the water table is within 1 m of the bottom of the infiltration trench.
- The depth to bedrock should be ≥ 1 m below the bottom of the infiltration trench to ensure adequate drainage.
- The minimum storage volume should be equal to the runoff from a 5 mm storm over the contributing area. This volume should be accommodated in the pervious pipe bedding/storage media without overflowing. The maximum storage volume should be equal to the runoff from a 25 mm storm over the contributing drainage area. The bedding should drain within 24 hours. The depth of the exfiltration storage can be calculated based on the native soil percolation rate.
- The storage media should consist of clear 50 mm diameter stone to promote filtration with a low clogging frequency.
- A non-woven geotextile should be used at the interface between the pipe bedding and the native soil to prevent native soil from clogging the voids in the storage media.

8.4.3 Grassed Swales

Historically, grassed swales were constructed primarily for stormwater conveyance. However, stormwater objectives have changed and now grassed swales are being used to store, infiltrate and convey road and on-lot stormwater runoff. The grass or emergent vegetation in the swale reduces flow velocities, prevents erosion, and filters stormwater pollutants.

Figure 8.10: Grassed Swale


100 - 300 mm
0.5% - 2.0% Grade
Optional 100 mm Perforated Pipe with filter sock
A
Swale Profile
Wooden Check Dam
5 - 60 m long
2 m wide
Swale Plan
1.25 m
A
1.25 m
0.75 m
0.5 m deep
2.5 : 1 side slopes
100 mm perforated pipe
Cross Sectional Profile A-A

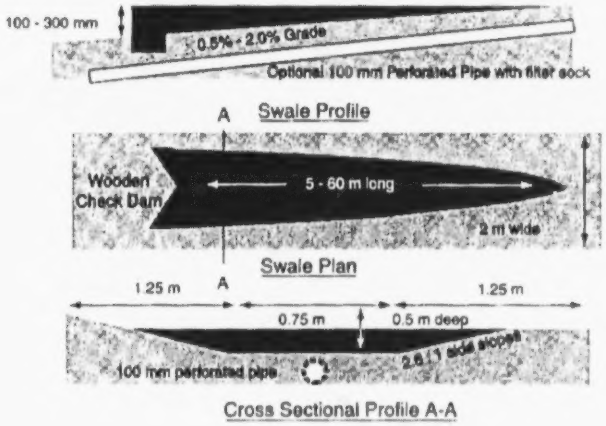
removal to prevent frequent clogging.

- Pervious catchbasins can be implemented for soil types with a minimum infiltration rate of 15 mm/hr or greater. This generally includes soils coarser than loam. Clay soils are not suitable.
- Pervious catchbasins should not be installed in areas with seasonally high water tables. This system should not be implemented where the water table is within 1 m of the bottom of the infiltration trench.
- The depth to bedrock should be ≥ 1 m below the bottom of the infiltration trench to ensure adequate drainage.
- The minimum storage volume should be equal to the runoff from a 5 mm storm over the contributing area. This volume should be accommodated in the pervious pipe bedding/storage media without overflowing. The maximum storage volume should be equal to the runoff from a 25 mm storm over the contributing drainage area. The bedding should drain within 24 hours. The depth of the exfiltration storage can be calculated based on the native soil percolation rate.
- The storage media should consist of clear 50 mm diameter stone to promote filtration with a low clogging frequency.
- A non-woven geotextile should be used at the interface between the pipe bedding and the native soil to prevent native soil from clogging the voids in the storage media.

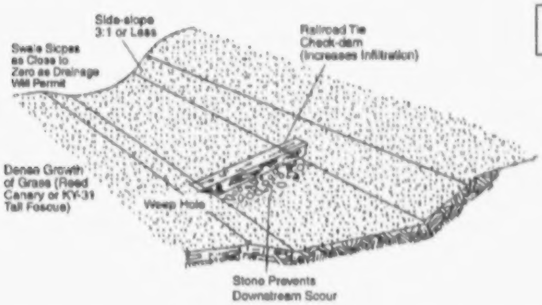
8.4.3 Grassed Swales

Historically, grassed swales were constructed primarily for stormwater conveyance. However, stormwater objectives have changed and now grassed swales are being used to store, infiltrate and convey road and on-lot stormwater runoff. The grass or emergent vegetation in the swale reduces flow velocities, prevents erosion, and filters stormwater pollutants.

Figure 8.10: Grassed Swale


100 - 300 mm
0.5% - 2.0% Grade
Optional 100 mm Perforated Pipe with filter sock
A
Swale Profile
Wooden Check Dam
5 - 60 m long
2 m wide
Swale Plan
A
1.25 m
1.25 m
0.75 m
0.5 m deep
2.6 : 1 side slopes
100 mm perforated pipe
Cross Sectional Profile A-A

Grassed Swale with Check Dam


Side-slope 3:1 or Less
Swale Slopes as Close to Zero as Drainage Will Permit
Railroad Tie Check-dam (Increases Infiltration)
Dense Growth of Grass (Reed Canary or KY-31 Tall Fescue)
Weep Hole
Stone Prevents Downstream Scour

Grass swales are effective BMPs for water quantity and quality, if designed properly. By promoting infiltration, runoff volumes can be reduced. As well, many stormwater contaminants can be effectively filtered such as heavy metals, COD, nitrate nitrogen, ammonia nitrogen, and suspended solids. However, water quality enhancement will be dependent on the contact area between the water and the swale and the longitudinal slope. Deep narrow channels are less effective for pollutant removal than shallow wide swales. Safety issues regarding conveyance depths and velocities must be taken into consideration.

Design Considerations

- Grassed swales should be designed with minimum longitudinal slopes of 1 to 2% to promote infiltration and filtering, yet maintain conveyance. When longitudinal slopes exceed 2 to 4%, check dams are normally used.
- Perforated pipe beneath the swale can used to ensure the swale remains dry between storm events.
- Side slopes for a grassed swale should be no greater than 2.5H:1V but should be 4H:1V ideally. A minimum bottom width of 0.75 m and a minimum depth of 0.5 m should be maintained.
- The maximum velocity in a grassed swale should be limited to 0.5 m/s maximum, otherwise check dams can be used. The erosion potential should be carefully considered as well.
- Grass should be local species or standard turf grass when a more manicured appearance is required. The grass should be allowed to grow higher than 75 mm to enhance the filtration of suspended solids.

8.5 Treatment BMPs

Treatment BMPs typically receive stormwater from conveyance systems such as ditches and sewers. These BMPs provide water quality enhancement of the stormwater prior to discharging into a receiving water body. Treatment BMPs have been referred to as end-of-pipe BMPs and are often the "last line of defence" after other source controls or BMPs have been applied. Treatment BMPs include wet ponds, dry ponds, wetlands, infiltration trenches, infiltration basins, and sand filters. Extended detention ponds and hybrid ponds are variations of wet ponds, dry ponds or wetlands and are included in these treatment BMPs. Typically, treatment or end-of-pipe BMPs are more efficient than source controls for controlling flows and providing pollutant removal.

8.5.1 Dry Ponds

Dry ponds temporarily store stormwater runoff and can be effectively used for erosion and quantity control. However, dry ponds have no permanent pool of water. Therefore, removal of stormwater contaminants is primarily a function of the drawdown time of the pond. Modelling studies by Perreault et al and Adams (1996) have indicated that substantial improvement in removal efficiency can be achieved if a 48 hour detention time is used. With limited water quality benefits, dry ponds will largely be restricted to water quantity control or as part of an overall treatment sequence approach. For further information, please refer to **Section 6.2 Dry Ponds**.

Dry ponds are suitable for large drainage areas. Use of dry ponds for combined water quantity and quality is discouraged without the use of sediment forebays that include a permanent pool.

Design Considerations

- Dry ponds are designed to meet specific water quantity objectives. For design information, please refer to **Section 6.0 Stormwater Ponds**.

8.5.2 Wet Ponds

Wet ponds temporarily store stormwater runoff in order to promote pollutant removal and to control discharge to predetermined levels to reduce downstream flooding and erosion. Wet ponds are one of the most common treatment BMPs used and are very effective in controlling runoff and improving water quality when properly designed. For further information, please refer to **Section 6.3 Wet Ponds**.

Wet ponds have a moderate to high capacity of removing most urban pollutants. They are particularly effective in removing sediments (TSS). The permanent pond in the wet pond is the primary source of water quality enhancement. Runoff entering the pond is slowed by the permanent pool and suspended pollutants are allowed to settle out. Other biological processes, such as nutrient uptake by algae, also help to reduce contaminants. The vegetation established in and around the pond provides shading, aesthetics, safety and enhanced pollutant removal. The inclusion of a forebay helps facilitate sediment removal as well.

Wet ponds are suitable for large drainage areas, and for residential, commercial, and industrial land uses.

Design Considerations

- Wet ponds are designed to meet specific water quantity and water quality objectives. For design information, please refer to **Section 6.0 Stormwater Ponds**.

8.5.3 Wetlands

Constructed wetlands retain runoff for prolonged periods of time and provide water quantity and quality control. Wetlands consist of relatively shallow extended detention areas with extensive plantings that make up the majority of the wetland's permanent storage. Sedimentation, filtration, biological and chemical processes account for the water quality improvement. Although many communities across Canada have installed wetlands, limited performance monitoring has been conducted (in Ontario). Therefore, the biological impacts and enhancements are not well understood. The impact of Calgary's climate is also not known; The City of Calgary is currently monitoring wetlands that have been constructed in Calgary. For further information, please refer to **Section 6.4 Wetlands.**

In general, wetlands have been found to lower BOD, TSS, and total nitrogen concentrations. For total phosphorous, metals and organic compounds, removal efficiencies vary widely and appear to be limited by substrate type, constituent forms, the presence of oxygen, and the chemical makeup of the water to be treated.

Wetlands are suitable for relatively large drainage areas, and for residential, commercial, and industrial uses. However, the influent must not contain high levels of industrial toxic pollutants, as this will adversely affect the wetland vegetation.

Design Considerations

- Wetlands are designed to meet specific water quantity and water quality objectives. For design information, please refer to **Section 6.0 Stormwater Ponds**.

8.5.4 Infiltration Basins

Infiltration basins are above-ground pond systems that are constructed in highly pervious soils to collect and temporarily store runoff and promote infiltration. The appearance of an infiltration basin is similar to that of a wet pond or dry pond. The infiltrated water either recharges the groundwater, or is collected by an underground perforated pipe system and discharged to a downstream outlet. Unfortunately, many of the infiltration basins have not been successful; failure rates in the United States range from 60% to 100% (Schueler 1992). Systems in Ontario have also had a high failure rate. High failure rates can be attributed to:

- poor site selection (poor soil type, high water table, industrial/commercial land use)
- poor design (inadequate surface area)
- poor construction techniques
- high sediment loadings due to large drainage areas
- lack of pre-treatment and/or bypass
- lack of maintenance

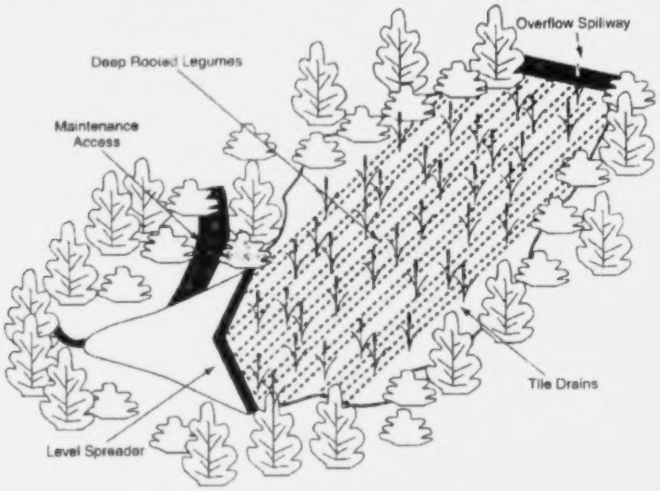


Figure 8.11: Infiltration Basin

Infiltration basins are generally ineffective for water quantity control since they can only infiltrate limited volumes of stormwater. As well, it is important that infiltration basins be used in conjunction with pre-treatment ponds (wet ponds, wetland or dry ponds) or filters to remove suspended solids and improve long-term performance.

Infiltration basins are generally suitable for drainage areas less than 5 ha. Underlying soils must be permeable, otherwise clogging will occur. Infiltration basins should only be implemented for residential land use. They are not recommended for industrial or commercial land use due to the high potential of groundwater contamination due to chemical spills and salting/sanding maintenance activities.

Design Considerations

- Infiltration basins should include a pre-treatment system for solids removal to prevent clogging of the basin.

- Infiltration basins can be implemented for soil types with a minimum infiltration rate of 60 mm/hr or greater. This generally includes loamy sands and sands. Clay soils are not suitable.
- Infiltration basins should not be installed in areas with seasonally high water tables. This system should not be implemented where the water table is within 1 m of the bottom of the basin.
- The depth to bedrock should be ≥ 1 m below the bottom of the infiltration basin bottom to ensure adequate drainage.
- The maximum water storage depth in the basin should be 0.6 m to minimize compaction. Compaction of the basin and smearing of the native material must be avoided.
- Planting in the basin should include grasses and deep rooted legumes to maintain or enhance the pore spaces in the soil.

8.5.5 Filters

Filters are treatment BMPs that promote pollutant removal. They can be constructed as either surface or subsurface devices. The filter is constructed with an impermeable liner to prevent the adjacent native material from clogging pore spaces, and to prevent filtered water from entering the groundwater. The infiltrated water is then collected into a pervious pipe system and conveyed to a downstream outlet. Surface filters are normally covered by a layer of grass.

Sand filters are the most common type of filter, but organic and bioretention filters are also available. Organic filters can also be designed as surface or subsurface devices. In an organic filter, there is an organic layer of peat in addition to the sand that enhances the removal of nutrients and trace metals. Bioretention filters are similar to surface filters but allow the integration of open space and landscaping areas.

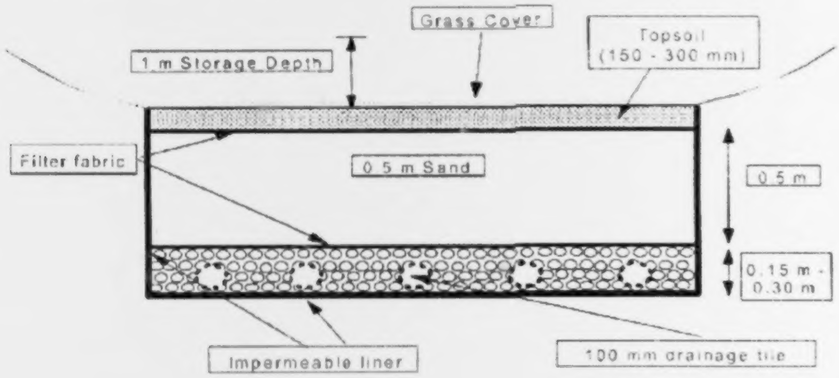


Figure 8.12: Sand Filter Cross Section

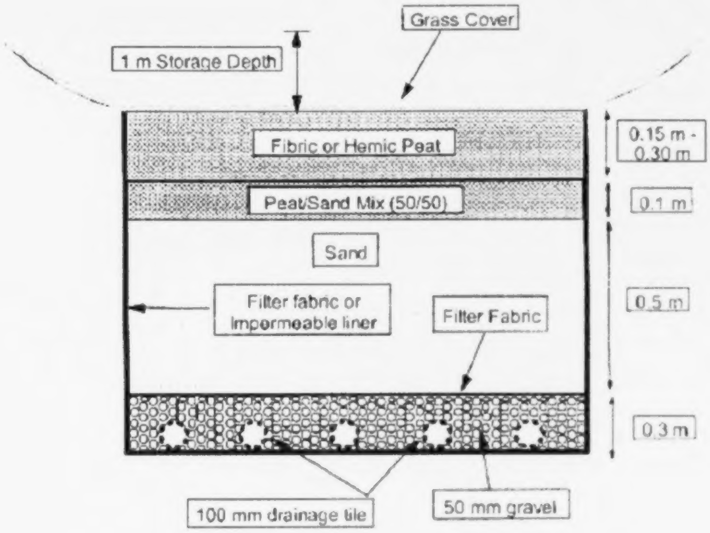

Grass Cover
1 m Storage Depth
Fibric or Hemic Peat
0.15 m - 0.30 m
Peat/Sand Mix (50/50)
0.1 m
Sand
Filter fabric or Impermeable liner
Filter Fabric
0.5 m
0.3 m
100 mm drainage tile
50 mm gravel

Figure 8.13: Sand-Peat Filter Cross Section

Filters are a water quality BMP and have no practical application for erosion or quantity control. Although sand filters have been found to be effective in removing pollutants, little is known about their performance in winter conditions.

Filters are generally suitable for drainage areas less than 5 ha. These filtration systems can be used in most parking lot areas and commercial sites. Otherwise, filters may be employed for any land use. Biofilters can be landscaped using trees, shrubs, or turf, but can also be used beneath hard surface landscaped areas such as courtyards, walkways and patios.

Design Considerations

- Filters should include a pre-treatment system for solids removal to promote longevity of the filter.
- It is recommended that the storage depth above a sand filter be limited to 1 m maximum to reduce the potential for compaction of the sand layer. Storage depths for surface filters and bioretention filters should be limited to 0.15 m to protect the vegetation.
- The recommended filter layer (media) depth for sand filters is 0.5 m, and 1.0 to 1.2 m for bioretention filters. For organic filters, a depth of 0.15 to 0.3 m is recommended for the peat layer, 0.1 m for the peat/sand layer, and 0.5 m for the sand layer.
- Filter fabric or an impermeable liner should be used at the interface between the filter material and the native soil to prevent clogging the voids in the storage media.

8.6 Pre-treatment and Special Purpose BMPs

8.6.1 Filter Strips

Filter strips are engineered conveyance systems that are designed to remove pollutants from overland runoff. Generally, filter strips treat small drainage areas (< 2 ha). A typical filter strip consists of a level spreader (to ensure uniform overland flow) and vegetation. It is the vegetation that filters out the pollutants and promotes infiltration of the stormwater.

There are generally two types of filter strips: grass filter strips, and forested filter strips. Further research is still required to compare the efficiency of these two types of filter strips for water quality enhancement. Filter strips are best utilized adjacent to buffer strips, watercourses or drainage swales since sheet flow from the filter strip is difficult to convey in a traditional conveyance system such as pipes or swales. They may be used along overland escape routes and in parks and other landscaped areas. Filter strips also serve as pre-treatment systems to other BMPs.

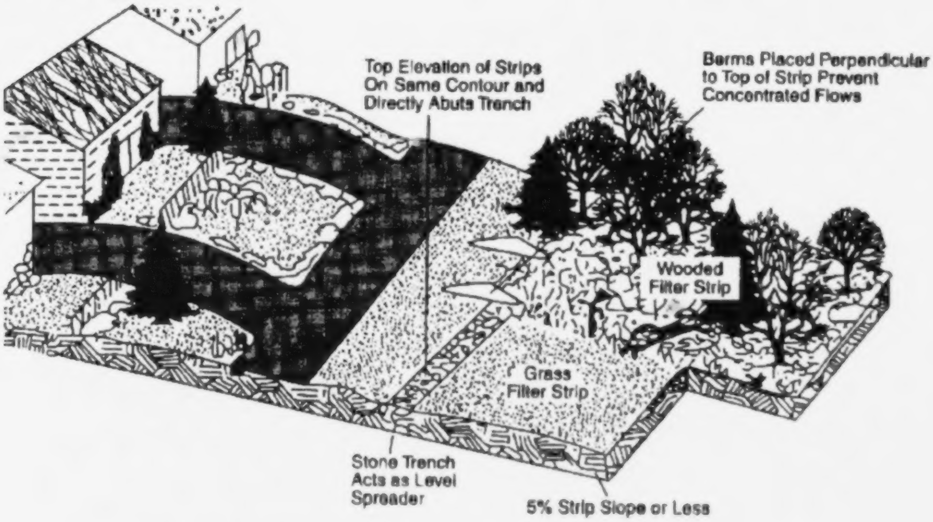

Top Elevation of Strips On Same Contour and Directly Abuts Trench
Berms Placed Perpendicular to Top of Strip Prevent Concentrated Flows
Wooded Filter Strip
Grass Filter Strip
Stone Trench Acts as Level Spreader
5% Strip Slope or Less

Figure 8.14: Grassed and Wooded Filter Strips

Filter strip performance data is limited although it is generally thought that properly designed filter strips are capable of removing a high percentage of stormwater pollutants. However, their ability to maintain sheet flow through the vegetation may be difficult. Stormwater volume may also be reduced slightly through the infiltration provided.

Design Considerations

- Filter strips typically treat small drainage areas (< 2 ha).

- A level spreader should be used to convey the runoff as sheet flow. Storage behind the spreader is required to regulate the discharge rate and the depth of flow through the filter strip.
- Filter strips should be located in flat areas (< 10%) to promote sheet flow and maximize filtration. The ideal slope is < 5%.
- Filter strips should be 10 to 20 m long in the direction of flow to provide sufficient water quality enhancement. The slope of the filter strip should dictate the actual length.

8.6.2 Buffer Strips

Buffer strips are natural areas between development and receiving waters. They are designed to protect the stream and valley corridor system, and to protect vegetated riparian areas within the valley system to minimize the impact of development on the stream itself (ie. filter pollutants, provide shade and bank stability, etc.). Although buffer strips may only provide limited benefits in terms of stormwater management, they are an integral part of the overall environmental management for development. The protection of stream and valley corridors provides significant benefits to wildlife, aquatic habitat, terrestrial habitat, and linkage between natural areas.

There are currently no specific design considerations required for buffer strips. Vegetation should be suited to the adjacent habitat and land uses. Use of MR and ER also provides potential usage. However, approval is required from Park Development & Operations for usage. Width of buffer strips should be reviewed with Park Development & Operations and Wastewater & Drainage.

8.6.3 Oil/Grit Separators

Oil/grit separators are a variation of the traditional settling tank that are designed to capture sediments and trap hydrocarbons (oils) in stormwater runoff. An oil/grit separator is an underground retention structure that takes the place of a conventional manhole in the storm sewer system. There are essentially two design types of oil/grit separators available, 3 chamber and bypass separator. Three chamber separators operate most effectively when constructed off-line; only low flows should be directed to the separator. Bypass separators should be installed on-line, as performance is not affected by high flows.

Oil/grit separators can provide effective treatment of stormwater runoff when used at the source or as pre-treatment. However, oil/grit separators vary in design and performance. Separators that do not incorporate a flow bypass have generally been found to be ineffective in removing and containing sediments and oils due to continuous re-suspension. Depending on land use, drainage area and site conditions, oil/grit separators may also be effective in reducing TSS. However, oil/grit separators are not designed to provide water quantity control. Wastewater & Drainage is currently testing and monitoring two brands of oil/grit separators for performance; contact Wastewater & Drainage for more information.

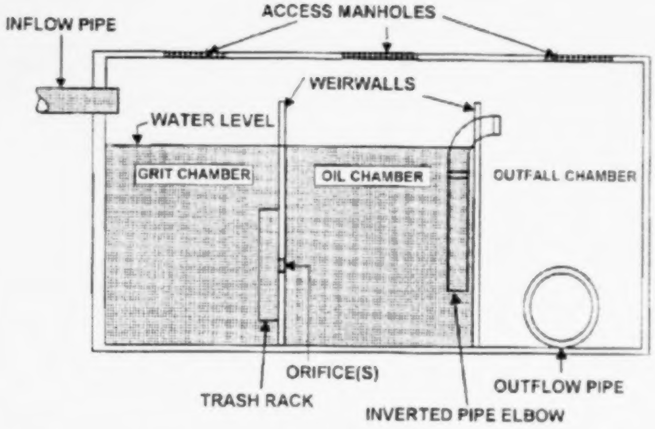

INFLOW PIPE
ACCESS MANHOLES
WEIRWALLS
WATER LEVEL
GRIT CHAMBER
OIL CHAMBER
OUTFALL CHAMBER
ORIFICE(S)
TRASH RACK
OUTFLOW PIPE
INVERTED PIPE ELBOW

Figure 8.15: 3 Chamber Oil/Grit Separator

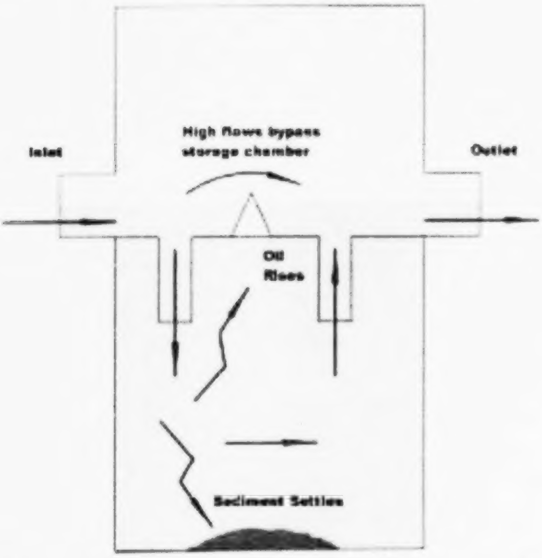

Inlet
High flows bypass storage chamber
Outlet
Oil Rises
Sediment Settles

Figure 8.16: Bypass Flow Oil/Grit Separator

Oil/grit separators are generally suitable for drainage areas smaller than 5 ha. They are best applied in areas of high impervious cover where there is potential for hydrocarbon spills and polluted sediment discharges. Typical applications include parking lots, commercial and industrial sites, gas stations, airports and residential developments (for pre-treatment). Regularly scheduled maintenance is required to maintain performance.

Design Considerations

- There are some suppliers that can provide oil/grit separators, design guidance, and performance information.

8.6.4 Porous Pavement

Porous pavement is an alternative to conventional pavement where runoff is diverted through a porous asphalt layer and into an underground storage layer. The stored runoff gradually infiltrates into the native soil. There are two types of porous pavement, porous asphalt pavement and pervious concrete pavement. Porous pavement provides both water quantity and quality control.

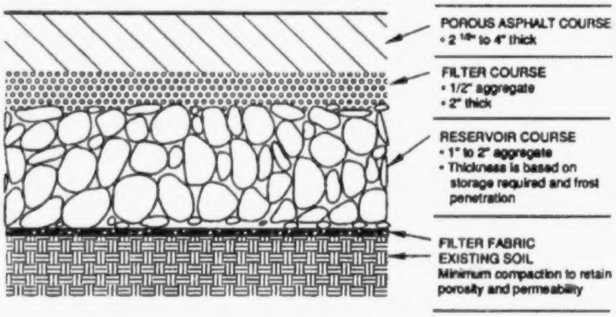

POROUS ASPHALT COURSE
• 2 1/2" to 4" thick
FILTER COURSE
• 1/2" aggregate
• 2" thick
RESERVOIR COURSE
• 1" to 2" aggregate
• Thickness is based on storage required and frost penetration
FILTER FABRIC
EXISTING SOIL
Minimum compaction to retain porosity and permeability

Figure 8.17: Porous Pavement

Porous pavement systems have been shown to have high removal rates for sediments, nutrients, organic matter, and trace metals. Unfortunately, porous pavement has a high failure rate (75%) due to clogging of the media. This clogging occurs immediately after construction, over time when the asphalt becomes clogged with sediment and oil, and when the pavement is re-surfaced with non-porous materials. Regular maintenance is required to maintain porosity.

Porous pavement can be used as a substitute for conventional asphalt pavement on parking areas and low-traffic volume roads. Use should be restricted in cold climate areas, arid region, regions with high wind erosion rates, or in areas where groundwater contamination is a concern. Drainage areas should be restricted to areas smaller than 5 ha.

Design Considerations

- Porous pavement can be implemented for soil types with a minimum infiltration rate of 15 mm/hr or greater. This generally includes soils coarser than loam. Clay soils are not suitable.

- Porous pavement should not be installed in areas with seasonally high water tables. This system should not be implemented where the water table is within 1 m of the bottom of the trench.
- The depth to bedrock should be ≥ 1 m below the bottom of the trench to ensure adequate drainage.
- Pavement slopes should be restricted to ≤ 5% to promote infiltration.

8.7 BMP Screening and Selection

To effectively implement a BMP system, it is essential for the designer to determine the most appropriate BMP based on the physical characteristics of the site and the intended usage of the site. A prudent designer will take advantage of a site's topography, and use his/her own experience and judgement, and the requirements of the municipality, to successfully design and implement these controls.

8.7.1 Physical Site Constraints

Soil Suitability

Soil suitability is a major consideration when designing BMPs, particularly when designing infiltration facilities and wet facilities or ponds. A soil investigation is recommended to determine whether the soil is suitable. Soil surveys, where available, also provide useful soil type information.

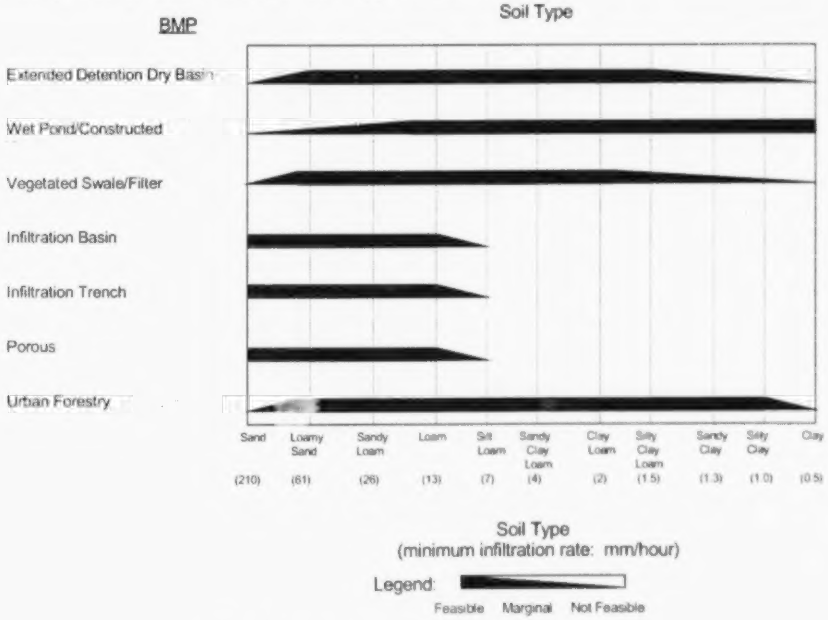


Table 8.1: Soil Type Restrictions

Calgary has a high degree of clay and clay-type soils (ie. silty clays, etc.) which affect soil infiltration rates. Typically, soils with less than a permeability of 6.8 mm/hr[9] are not suitable for infiltration BMPs. However, there are different areas in Calgary where the soils may be suitable (ie. gravel beds near rivers) and infiltration BMPs may be appropriate.

Depth to Water Table

The effectiveness of infiltration BMPs is impacted by the depth to the water table. High water tables affect the movement of water from the BMP to the underlying soil. The size and shape of the BMP, along with the hydrological properties of the soil, determine the impact of the water table elevation on infiltration performance. For screening purposes, soils having high water tables less than 1.2 m below the ground surface are unsuitable for infiltration.

Depth to Bedrock

The depth of bedrock is an important consideration for infiltration BMPs. A shallow depth to bedrock can impede exfiltration of water from BMPs into the underlying soil. As well, the depth to bedrock may impact the excavation process for ponds.

Topography

The topography or slope of a site will limit the type of BMP that can be utilized on a particular site. Slopes for grassed swales and porous pavement should not exceed 5% to be effective. Infiltration trenches should be limited to slopes of 20% maximum. As well, infiltration trenches should not be used in fill sites due to the risk of slope failure.

Drainage Area

The size of the drainage area to be served by a BMP is an important consideration. If the drainage area is too large, the BMP will not be effective. In this situation, other BMPs or a combination of BMPs should be utilized to be more efficient and/or cost effective.

Site Usage

Site usage will also have an impact on the BMP selection. A BMP should be located where the expected zone of saturation will not affect building foundations, fill slopes, retaining walls, basements, or potable water supplies.

---

[9] Northern Virginia Planning District Commission, *"Northern Virginia BMP Handbook: A Guide to Planning and Designing Best Management Practices in Northern Virginia"*, 1992

BMPs may also be affected by land availability being limited or cost prohibitive. Therefore, the amount of land required by the BMP must be carefully considered. As well, recreational uses may have to be incorporated, since BMPs may potentially utilize recreational space.

Finally, BMP locations can potentially impact aquatic and wildlife habitat. Sites with high wildlife habitat values should be avoided and/or efforts made to minimize adverse impacts or disruption of the wildlife corridors. Opportunities to enhance or protect wildlife habitat should be pursued. Habitat values should be carefully considered during site screening, planning, design, preparation and construction of BMPs.

Table 8.2 provides a summary of some of the physical constraints associated with the various BMPs.

Table 8.2:
Physical BMP Constraints

BMP	**Criteria**				
	Topography	**Soils**	**Bedrock**	**Groundwater**	**Area**
Lot-Level BMPs					
Flat lot grading	<5%	none	None	none	none
Soak-away pit	None	loam (min. infiltration rate ≥ 15 mm/h)	>1 m below bottom	>1m below bottom	<0.5 ha
Rear yard infiltration	<2%	loam (min. infiltration rate ≥ 15 mm/h)	>1 m below bottom	> 1m below bottom	<0.5 ha
Infiltration trench	none	loam (min. infiltration rate ≥15 mm/h)	>1 m below bottom	>1 m below bottom	<2 ha
Conveyance BMPs					
Grassed swales	<5%	none	None	none	none
Perforated pipes	none	loam (min. infiltration rate ≥ 15 mm/h)	>1 m below bottom	>1 m below bottom	none
Previous catchbasins	none	loam (min. infiltration rate ≥ 15 mm/h)	>1 m below bottom	>1 m below bottom	none
Treatment and Pre-Treatment BMPs					
Wet pond	none	none	none	none	>5 ha
Dry pond	none	none	none	none	>5 ha
Wetland	none	none	none	none	>5 ha

Infiltration basin	none	loam (min. infiltration rate ≥15 mm/h)	>1 m below bottom	>1 m below bottom	<5 ha
Filter strips	<10%	none	none	>0.5 m below bottom	<2 ha
Sand filters	none	none	none	>0.5 m below bottom	<5 ha
Oil/grit separators	none	none	none	none	<1 ha

8.7.2 Initial Screening

There is a wide range of BMPs available. Selection of the appropriate BMP or group of BMPs will be dependent on the stormwater objectives for the area and any physical site constraints. Overall effectiveness should include both water quantity and water quality objectives.

Each stormwater BMP has certain advantages and disadvantages that may reduce the number of options available for a particular area. Table 8.3 summarizes these advantages and disadvantages.

Table 8.3:
BMP Advantages and Disadvantages

BMP	Advantages	Disadvantages
Wet pond	• Capable of removing soluble as well as solid pollutants • Provides erosion control • Habitat, aesthetic, and recreation opportunities provided • Relatively less frequent maintenance schedule	• More costly than dry ponds • Permanent pool storage requires larger land area • Could have negative downstream temperature impacts • Could be constrained by topography or land designations • Sediment removal relatively costly when required
Dry pond	• Batch mode has comparable effectiveness to wet ponds • Not constrained by land area required by wet ponds • Can provide recreational benefits	• Potential re-suspension of contaminants • More expensive O&M costs than wet ponds (batch mode)
Wetlands	• Pollutant-removal capability similar to wet ponds • Offers enhanced nutrient-removal capability • Potential ancillary benefits, including aviary, terrestrial, and aquatic habitat	• Requires more land area than wet ponds • Could have negative downstream temperature impacts • Could be constrained by topography or land designations • Potential for some nuisance problems
Infiltration Trenches	• Potentially effective in promoting recharge and maintaining low flows in small areas • May be appropriate as secondary facility where maintenance of groundwater recharge is a concern • No thermal impact • No public safety concern	• Appropriate only to small drainage areas (<2 ha) and residential land uses • Constrained by native soil permeabilities • Usually requires pre-treatment device • Potential contamination of groundwater must be investigated • Generally ineffective for water quantity control • High rate of failure due to improper siting and design, pollutant loading, and lack of

Table 8.3:
BMP Advantages and Disadvantages

BMP	Advantages	Disadvantages
		maintenance
Infiltration Basins	• Potentially effective in promoting recharge and maintaining low flows in small areas • May be appropriate as secondary facility where maintenance of groundwater recharge is a concern • No thermal impact • No public safety concern	• Appropriate only to relatively small drainage areas (<5 ha) and residential land uses • Constrained by native soil permeabilities • Pre-treatment is recommended • Potential contamination of groundwater must be investigated • Generally ineffective for water quantity control • High rate of failure due to improper siting and design, pollutant loading, and lack of maintenance
Filter Strips	• Water quality benefits may be realized if part of an overall stormwater management plan (i.e., as secondary facility) • Effective in filtering out suspended solids and intercepting precipitation • May reduce runoff by reducing overland flow velocities, increasing time of concentration, and increasing infiltration • Can create wildlife habitat • No thermal impact	• Limited to small drainage areas (<2 ha) with little topographic relief • Uniform sheet flow through vegetation difficult to maintain • Effectiveness in freeze/thaw conditions questionable
Filters	• Generally effective in removing pollutants, are resistant to clogging and are easier/less expensive to retrofit compared to infiltration trenches	• Not suitable for water quantity control • Generally applicable to only small drainage areas (<5 ha) • Do not generally recharge groundwater system • May cause aesthetic/odour problems • O&M costs generally higher than other end-of-pipe facilities
Oil/Grit Separators (3-Chamber Separator)	• Offline, 3-chamber (oil, grit, discharge) separators may be appropriate for commercial, industrial, large parking, or transportation-related areas less than 2 ha	• Scour and re-suspension of trapped pollutants in heavy rainfall events • Difficult to maintain • Relatively high O&M costs • Online design of 3-chamber separators has resulted in poor pollutant removal performance
Oil/Grit Separators (Bypass Separator)	• Bypass prevents the scouring and re-suspension of trapped pollutants in heavy rainfall events • Effective in removing sediment load when properly applied as a source control for small areas • Effective in trapping oil/grease from runoff	• Relatively high capital costs compared to manholes • Applicable for drainage areas less than 5 ha

8.7.3 Final Screening

In the initial screening, BMPs are limited by particular disadvantages and site constraints. The remaining feasible BMPs should then be further screened with the application of specific objectives pertaining to water quality, water quantity (flooding), erosion and recharge potential. These opportunities are identified in Table 8.4. Long term operating and maintenance also need to be considered. For further information on the effectiveness of BMPs to remove pollutants, please refer to Alberta Environment's "Stormwater Management Guidelines for the Province of Alberta" (1999).

Table 8.4:
Potential BMP Opportunities

Stormwater BMP	Water Quality	Water Quantity (Flooding)	Erosion	Recharge
Lot-Level BMPs				
Lot grading	♦	♦	♦	•
Roof Leader ponding	♦	♦	♦	•
Roof leader soak-away pits	♦	♦	♦	•
Infiltration trench	♦*	♦	♦	•
Conveyance BMPs				
Pervious pipes	•*	♦	♦	•
Pervious catchbasins	•*	♦	♦	•
Grassed swales	•	♦	•	♦
Treatment and Pre-Treatment BMPs				
Wet pond	•	•	•	○
Dry Pond	♦	•	•	○
Dry pond with forebay	•	•	•	○
Wetland	•	•	•	○
Sand filter	•	♦	♦	○
Infiltration basin	♦*	♦	♦	•
Vegetation filter strip	•	○	♦	♦
Buffer strip	♦	○	♦	♦
Oil/grit separator	♦	○	○	○

• Highly effective (primary control)
♦ Limited effectiveness (secondary control)
○ Not effective
* May have adverse effects
From MOEE, 1994

8.8 Cold Climate Impacts

Designing effective stormwater BMPs is not an easy challenge. Cold climates present additional challenges that make some traditional BMP designs less effective or unusable. Care should be taken when designing BMPs for Calgary's cold climate and chinooks. Some of the challenges to be considered include:

Table 8.5: Cold Climate Challenges

Climatic Condition	BMP Design Challenge
Cold Temperatures	• Pipe freezing • Permanent pool ice-covered • Reduced biological activity • Reduced oxygen levels during ice cover • Reduced settling velocities
Deep Frost Line	• Frost heaving • Reduced soil infiltration • Pipe freezing
Short Growing Season	• Short time period to establish vegetation • Different plant species appropriate to cold climates than moderate climates
Snowfall	• High runoff volumes during snowmelt and rain-on-snow events • High pollutant loads during spring melt • Impacts of road salt/de-icers • Snow management may affect BMP storage

8.9 Operation and Maintenance

All BMPs require inspection and maintenance to ensure proper operation. However, there can be a significant difference in the degree of maintenance required for efficient performance. Selection of a BMP should consider maintenance requirements in terms of cost, responsibility, feasibility and access.

The main screening consideration should be the frequency of maintenance required for the BMP. Limited staff resources and lack of maintenance can result in ineffective BMP operation. In general, infiltration BMPs will require the most maintenance to ensure the soils do not become clogged. Sediment control systems installed upstream of infiltration BMPs will help long-term maintenance of infiltration BMPs. Regularly scheduled maintenance will also help alleviate problems.

Maintenance costs is the second screening consideration that should be considered. Currently, the City of Calgary does not have an adequate record of maintenance costs for BMPs, other than those for ponds. However, information from other municipalities can be used as a general guideline. Maintenance costs are borne by land owners for BMPs on private property.

Regular inspection and maintenance must be scheduled for **all** BMPs. Since little maintenance data is available, the frequency and scope of the inspections and maintenance will have to be developed by trial and error. Information from other municipalities, where available, can be used as a reference.

9.0 Erosion & Sediment Control

9.1 Introduction

Stormwater runoff is part of the natural hydrological cycle. However, human activities, in particular urbanization, can have a profound impact on the quality of Calgary's rivers, streams and creeks. The hydrology of a site changes during construction. Trees, meadows, grasses and agricultural crops that once intercepted and absorbed rainfall are removed and natural depressions that temporarily ponded runoff are graded over. The cleared sites increase imperviousness and stormwater runoff.

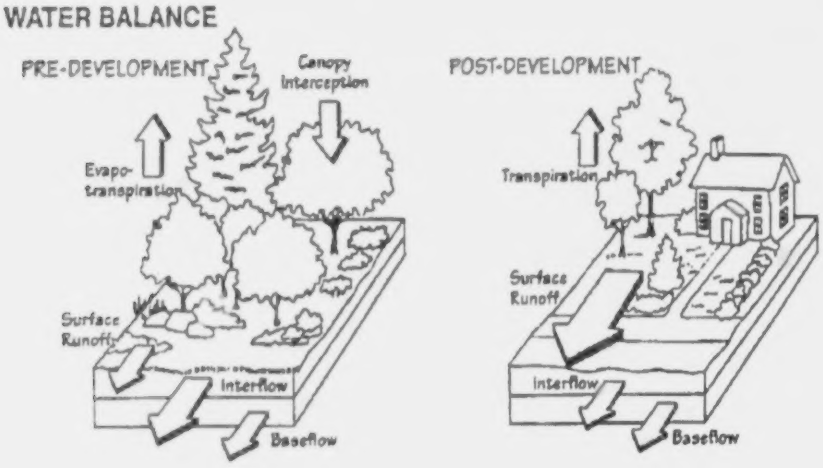


Figure 9.1: Water Balance at Undeveloped and Developed Sites (Schueler, 1987)

Construction activities can result in a rapid increase in erosion and sedimentation, and if left uncontrolled, can irreparably harm the environment, resulting in loss of valuable topsoil, and the subsequent sedimentation of rivers and other water bodies. Sedimentation of our rivers, streams and creeks can negatively affect water supplies, flood control, fish habitat and fishing, navigation and recreational activities. On average, erosion rates for construction sites with no erosion control measures are 200-400 times higher than natural erosion rates for rural land use.

It is important that our water resources are protected from erosion of the land or pollution caused by construction activities and other harmful activities. The costs associated with these damages can be significant. However, erosion and sediment control techniques can help protect these valuable resources by reducing the environmental impacts caused by sediment entering our receiving streams.

9.1.1 Erosion & Sedimentation Process

Erosion

Soil erosion is the removal and loss of soil by the actions of water, ice, gravity or wind. In construction activities, soil erosion is caused by the force of falling and flowing water, resulting in the detachment and transport of soil particles. The force of raindrops falling on bare or sparsely vegetated soils is picked up and carried along with water running on the ground. As the runoff gains velocity and increases in sediment concentration, more soil particles detach, cutting rills and gullies into the surface. This has the potential to carry significant amounts of sediment into watercourses during and immediately after rainstorm events.

Sedimentation

Sedimentation (or deposition) is the settling out of soil particles transported by water. It can occur in slower-moving, quiescent waterbodies, or in treatment facilities such as stormwater ponds.

When the velocity of the water, in which soil particles are suspended, is slowed for a sufficient period of time, particles will settle out depending on their weight. Heavier particles such as sand and gravel will settle out more rapidly than fine particles of clay and silt.

Often clay particles will not settle out for extended periods of time due to their weight. As a result, settling by gravity is often ineffective and high turbidity can result. Turbidity can have detrimental effects on an aquatic environment (see Table 9.1). Treating stormwater for turbidity can be an expensive and difficult process. Therefore, any prevention measures that reduce turbid water or the volume of turbid water that must be treated, is beneficial.

Table 9.1: Impact of Suspended and Deposited Sediments on the Aquatic Environment[10]

Suspended Sediments	Deposited Sediments
• Abrades and damages fish gills, increasing risk of infection and disease • Scouring of plants attached to rocks • Loss of sensitive or threatened fish species when turbidity exceeds 25 NTU • Shifts in fish community toward more sediment tolerant species • Decline in sediment tolerant fish species when monthly turbidity exceeds 100 NTU • Reduces sight distance for trout, with reduction in feeding efficiency	• Physical smothering of benthic insect community • Reduced survival rates for fish eggs • Destruction of fish spawning areas and redds • Imbedding of stream bottom reduces fish and macroinvertibrate habitat value • Loss of trout habitat when fine sediments are deposited in spawning or riffle-runs • Sensitive or threatened fish species may be eliminated from fish community • Increase in sediment oxygen demand can deplete dissolved oxygen in lakes or streams

---

[10] Center for Watershed Protection, "*Watershed Protection Techniques*", Vol. 2, No. 3, February 1997

Suspended Sediments	Deposited Sediments
• Reduces light penetration causing reduction in plankton and aquatic plant growth • Reduces filtering efficiency of zooplankton in lakes and estuaries • Adversely impacts aquatic insects which are the base of the food chain • Slightly increases stream temperature in summer • Suspended sediments are a major carrier of nutrients and metals • Turbidity increases probability boating, swimming and diving accidents • Increased water treatment costs to meet drinking water standards • Increased wear and tear on hydroelectric and water intake equipment • Reduces anglers chances of catching fish • Diminishes direct and indirect experience of receiving waters	• Significant contributing factor in the decline of freshwater mussels • Reduced channel capacity, exacerbating downstream bank erosion and flooding • Reduced flood transport capacity under bridges and through culverts • Loss of storage and lower design life for reservoirs, impoundments and ponds • Dredging costs to maintain navigable channels and reservoir capacity • Spoiling of sand beaches • Deposits diminish the scenic and recreational value of waterways

The erosion process involves three basic stages: detachment, transport and deposition. Once sediment is detached from the land surface, the transport and deposition stages will determine how far the sediment is moved and where it will be deposited.

9.1.1.1 Types of Erosion

There are generally four types of erosion that result from water:

Raindrop Erosion: The direct impact of falling drops of rain on soil, causes the dislodging of soil particles so they can be easily transported by surface runoff.

Sheet Erosion: This type of erosion is caused by the removal of a layer of exposed surface soil by the action of raindrop splash and runoff, as water moves in broad sheets over the land.

Rill and Gully Erosion: As runoff flows, it concentrates in rivulets, cutting grooves called rills into the soil surface. If water flow is sufficient, rills will develop into larger gullies.

Stream and Channel Erosion: Increased volume and velocity of runoff in an unprotected, confined channel may cause stream meander instability, scouring, and erosion of stream or channel banks and bottom.

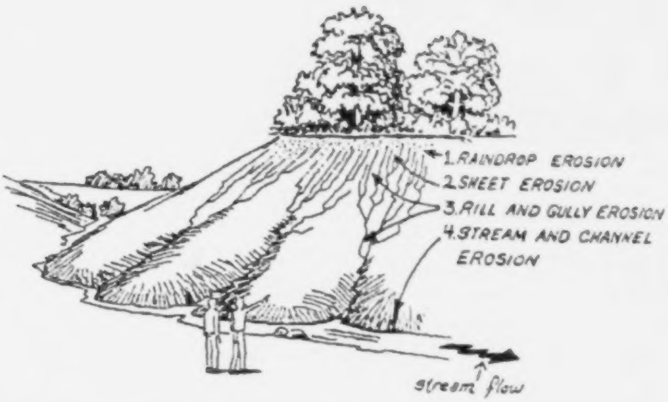


Figure 9.2: Types of Erosion

Soil erosion by wind creates a water quality problem when dust is blown into water. The lack of dust control during construction can be a significant problem. It can affect nearby sensitive habitat and wildlife areas, contribute to the accumulation of sediments and sediment transport in adjacent developed areas, and exacerbate dust and pollutant allergies in humans. Dust control is becoming a major consideration in erosion and sedimentation control.

9.1.1.2 Factors Influencing Erosion

The soil erosion potential of an area is determined by:

Soil Characteristics

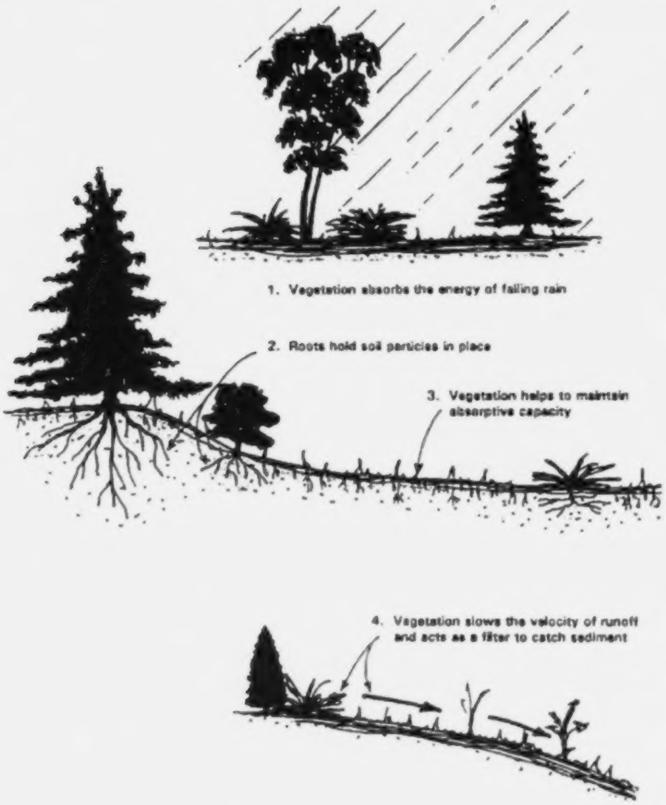
Erosion is influenced by soil properties such as particle size, organic content, soil structure and soil permeability. These factors affect the infiltration capacity of a soil and the resistance of the soil to erodibility. Soils containing high proportions of silt and very fine sand are usually the most erodible. Erodibility is decreased as the percentage of clay or organic matter increases. However, once eroded, clays are easily transported.

Organic matter, particle size and gradation affect the soil structure by the arrangement, orientation and organization of particles. In general, well-drained and well-graded gravels and gravel mixtures with little or no silt are the least erodible soils.

Vegetative Cover

Vegetative cover helps control erosion by shielding the soil surface from rainfall, slowing the velocity of runoff, maintaining the soil's absorption capacity, and holding soil particles in place. Soil erosion can be reduced by limiting the removal of existing vegetation and decreasing exposure time of denuded areas.

Figure 9.3: Effects of Vegetative Cover on Stormwater Runoff


1. Vegetation absorbs the energy of falling rain
2. Roots hold soil particles in place
3. Vegetation helps to maintain absorptive capacity
4. Vegetation slows the velocity of runoff and acts as a filter to catch sediment

Topography

The amount and rate of stormwater runoff is affected by the size, shape and relative elevation differences of the watershed or construction area. These unique characteristics can provide both opportunities and limitations for the use of specific control measures. Slope length, steepness, and orientation are all factors that should be considered.

Climate

Climate, and its associated weather, rainfall and rainstorm events, is somewhat predictable by seasonal and historic records. While the timing of a rainfall event is not predictable, the risks can be minimized by appropriate planning and using properly designed management practices and techniques. During the winter, chinooks can create potential erosion concerns due to lack of snow cover and an increase in wind erosion.

9.1.2 Goals & Objectives

The main objective is to protect our watercourses from pollution, primarily sediment pollution. Most sediment concerns have arisen due to urbanization of rural areas through the construction process. Development has increased the availability of sediment material and contaminants. The objective of sediment and erosion control is to prevent pollution by limiting the amount and rate of erosion occurring on disturbed sites and by capturing eroded soil before it leaves the construction site. The best strategy for managing sediment and erosion control is to direct efforts towards prevention of problems. One of the most effective ways to prevent sediment from entering and degrading watercourses is to control it at the source. Planning, design and construction can help reduce or avoid the impacts of erosion and sedimentation. However, such controls must be planned in advance and implemented during the development phase. This requires a new attitude towards carrying out construction activities. It is also important that **everyone** participate and contribute towards successful implementation to protect our watercourses. This includes the City of Calgary, developers/land owners, consultants, contractors, road builders, home builders, and homeowners.

Equally important for effective sediment and erosion control is the need for regular inspection and maintenance, and to make repairs as required. The construction phase of a project or development is usually considered a temporary condition, which will normally be replaced by permanent structures and facilities. However, the construction work may take place over an extended period of time. Any management practices and control facilities should be of sufficient size, strength and durability to outlast the expected construction schedule. The main objective of pollution prevention is to anticipate and avoid stormwater-generated situations that delay construction, add costs to the project, result in blame, and cause immediate and long-term environmental loss and degradation.

The implementation of erosion and sediment controls measures are not intended as rigid procedures, since it is anticipated that those responsible for the implementation will continue to utilize innovative approaches which best address specific situations. It is important to note that the nature of existing and proposed development, modifications to watercourses, and inherent tolerances in calculations and design techniques, may have significant impacts on the accuracy of outputs and on the preferred approach. Advances in technology will also continue to improve the methods and techniques that are currently employed. It is expected that the implementers will give due recognition to these factors during the decision-making process.

9.1.3 Applicable Design Documents

The City of Calgary "Guidelines for Erosion & Sediment Control" is the governing manual for erosion and sediment control. Specific details regarding erosion and sediment controls can be found in this manual. The manual was developed by Wastewater & Drainage. It should be noted that the *Erosion & Sediment Control* section in this stormwater manual is not intended to replace these guidelines, but to supplement them.

Where possible, **Section 8.0 Best Management Practices** in this manual and Alberta Environment's "Stormwater Management Guidelines" (1999) should be used as additional reference in the development of Erosion & Sediment Control (ESC) plans.

9.1.4 Regulatory Requirements

Erosion from land surfaces can contribute large quantities of sediment to watercourses, which not only leads to the accumulation of sediment, but it can affect clogging of water intakes, destruction of fish habitat and other aquatic organisms, increased dredging, and discharge of contaminants. The erosion control process can result in significant benefits to the aquatic ecosystem.

There are a number of federal, provincial and municipal acts and/or legislation governing either urban development or sediment control in general. Some of these are discussed in more detail in **Section 2.0 Approvals and Processes**.

9.1.4.1 Federal

Navigable Waters Protection Act

The *Navigable Waters Protection Act* applies to in-stream work. Section 21 of the Act states:

"No person shall throw or deposit or cause, suffer or permit to be thrown or deposited any sawdust, edging, slabs, bark or like rubbish of any description whatever that is liable to interfere with navigation in any water, any part of which is navigable or that flows into any navigable water."

while Section 22 states:

"No person shall throw or deposit or cause, suffer or permit to be thrown or deposited any stone, gravel, earth, cinders, ashes or other material or rubbish that is liable to sink to the bottom in any water, any part of which is navigable or that flows into any navigable water, where there are not at least twenty fathoms of water at all times, but nothing in his section shall be construed so as to permit the throwing or depositing of any substance in any part of a navigable water where that throwing or depositing is prohibited by or under any other Act."

Contravention of sections 21 and 22 may be liable to a fine not exceeding five thousand dollars for each offence.

Fisheries Act

The *Fisheries Act* applies to urban development and sediment control in general. Section 35 of the *Fisheries Act* states that "no person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat." Section 36 of the act regulates deposition of any substance (which would include sediment) which is deemed "deleterious" in waters frequented by fish. This act is regulated by the Department of Fisheries and Oceans.

9.1.4.2 Provincial

Environmental Protection and Enhancement Act

The purpose of the *Environmental Protection and Enhancement Act* is to support and promote the protection, enhancement and wise use of the environment. Under part 4, section 98 of the act:

(1) No person shall ***knowingly*** release or permit the release into the environment of a substance in an amount, concentration or level or at a rate of release that causes or may cause a significant adverse effect.

(2) No person shall release or permit the release into the environment of a substance in an amount, concentration or level or at a rate of release that causes or may cause a significant adverse effect.

One of the definitions of substance is "any matter that is capable of becoming dispersed in the environment". This includes erosion resulting from construction activities.

Release of such substances is enforceable by Alberta Environment. Contravention of (1) may result in a fine of not more than $100,000 or to imprisonment for a period of not more than 2 years, or to both a fine and imprisonment, in the case of an individual. In the case of a corporation, this may result in a fine of not more than $1,000,000.

Contravention of (2) may result in a fine of not more than $50,000 in the case of an individual, or not more than $500,000 in the case of a corporation.

Release Reporting Regulation (Alberta Regulation 117/93)

The Release Reporting Regulation is part of the Environmental Protection and Enhancement Act (EPEA) and deals with reporting requirements. Under section 99 of the EPEA, "a person who releases or causes or permits the release of a substance into the environment that has caused, is causing or may cause an adverse effect shall, as soon as that person knows or ought to know of the release, report it". Subsection 1 identifies the people that the incident should be reported to.

Pursuant to section 100 of the EPEA, a person who is required to report to the Director shall report in person or by telephone and shall include a report. Section 4 of the *Release Reporting Regulation* outlines the requirements for a written report. If an oral report is made within 7 days, the Director may waive the requirement for a written report.

Water Act

Lack of erosion and sediment control may also contravene the *Water Act*. Pursuant to Section 36, subsection (2) of the *Water Act*, an approval ***may*** be required for:

(i) placing, constructing, operating, maintaining, removing or disturbing works, maintaining, removing or disturbing ground, vegetation or other material, or carrying out any undertaking, including but not limited to groundwater exploration, in or on any land, water or water body, that

  (A) alters, may alter or may become capable of altering the flow or level of water, whether temporarily or permanently, including but not limited to water in a water body, by any means, including drainage,
  (B) changes, may change or may become capable of changing the location of water or the direction of flow of water, including water in a water body, by drainage or otherwise,
  (C) causes, may cause or may become capable of causing the siltation of water or the erosion of any bed or shore of a water body, or
  (D) causes, may cause or may become capable of causing an effect on the aquatic environment;

(ii) altering the flow, direction of flow or level of water or changing the location of water for the purposes of removing an ice jam, drainage, flood control, erosion control or channel realignment or for a similar purpose;

However, according to Schedule 1, section 2, an activity such as stripping or grading may be exempt if:

(d) landscaping that is not in a watercourse, lake or wetland if the landscaping does not result in
    (i) an adverse effect on the aquatic environment on any parcel of land, or
    (ii) any change in the flow or volume of water on an adjacent parcel of land;

Alberta Environment should be consulted for more information.

9.1.4.3 Municipal

During the construction process, Drainage Authorization is required from Wastewater & Drainage (Supervisor of Sewer Inspections) before any water may be disposed of through the City's storm sewer system. See City of Calgary "Standard Specifications Sewer Construction".

Drainage Bylaw 26M98

In 1998, the City of Calgary implemented the *Drainage Bylaw*. Pursuant to section 3, subsection 3, where an excavation of a parcel has been authorized by the issuance of a building, excavation or other municipal permit, water may be directed from the site into a storm catch basin within the storm drainage collection system but

(a) silt and debris shall be filtered to prevent them entry to the storm drainage collection system

Contravention of the drainage bylaw is punishable by a fine not exceeding $10,000 or imprisonment for a period not exceeding one year, or to both fine and imprisonment. An enforcement officer may, in addition to any other remedy at law, serve upon the person a violation ticket, allowing payment of the specified penalty. Recording of the payment shall constitute acceptance of a guilty plea and the imposition of a fine in the amount specified in Schedule B. Under Schedule B, first offence of 3(3) will result in a fine of $500; second and third offences are punishable with fines of $1000 and $2000 respectively.

The City of Calgary is committed to providing water quality for stormwater runoff. Therefore, during development and construction of both large and small parcels of land, control of erosion and implementation of sedimentation practices is essential.

Streets Bylaw 20M88

The *Streets Bylaw* was implemented in 1988. Section 16 of the bylaw states:

"No person shall place, dispose, direct or allow to be placed, or disposed, any Material belonging to such person or over which that person exercises control of such Material, on any portion of a Street."

"Material" is defined as "any object or article, animal waste, ashes, building waste, dry refuse, garbage, industrial chemical waste, refuse and yard waste as defined in the Waste Bylaw, and includes sand, gravel, earth and building products."

Violation of this section may result in an Enforcement Officer issuing a warning directing the removal of the Material. Failure to head the warning may result in Work Forces performing the work at the expense of the person responsible.

As well, section 19 of the bylaw states:

"No person shall dispose of anything into a sewer, manhole, or catchbasin excepting those persons authorized by issuance of a permit by the City Engineer and at those sites authorized and designated as dumping stations by the City Engineer."

A person contravening any provision of this bylaw shall, upon summary conviction before a court of competent jurisdiction, be liable to a fine of not more than $2500 or in the event of non-payment of the fine, imprisonment for a period not exceeding 90 days unless such fine is sooner paid.

9.1.5 Responsibilities

Erosion and sediment control is ultimately the responsibility of the property owner, which is typically the developer or landowner. Although the developer/land owner has prime responsibility,

Erosion and Sediment Control is Everyone's Responsibility!

Everyone has a role in protecting our watercourses through erosion and sediment control. This includes:

- City of Calgary
- Developers/Land Owners
- Consultants

- Contractors
- Road Builders
- Home Builders
- Homeowners

Training and public education are essential to making erosion and sediment controls work. The City of Calgary will endeavour to provide training to the appropriate parties on a regular basis and to conduct a public education program for homeowners and builders.

9.2 Planning

An Erosion and Sediment Control (ESC) Plan must be developed and submitted to the City of Calgary-Urban Development Department in order to obtain a stripping and grading permit for construction. The ESC Plan, usually in the form of a report, is circulated to Wastewater & Drainage for review and approval. Site and drainage planning should occur concurrently with site grading and erosion control planning.

Why Erosion & Sediment Control Plans Fail

A survey of ESC programs conducted by Brown and Caraco (1996) in the United States discovered that 10% of ESC programs appear to exist only on paper. Insufficient staffing prevented adequate plan review or inspection.

It is important to understand the reasons why ESC plans fail. Firstly, many ESC plans are not well integrated with other stream protection efforts occurring during construction. Construction is potentially the most destructive stage in the development with the removal of topsoil and trees, soil exposure, steep slope cutting, alteration of natural topography and drainage, wetland filling and riparian areas disturbed. An ESC Plan is more than preventing sediment from leaving the site; it should clearly outline where and how stream protection measures, such as wetland protection, forest conservation, stream buffers and BMPs, should be employed. It is important that stream protection measures be clearly marked on the plan. It is also important to know the sensitivity of the site and receiving stream.

All too often, ESC programs are developed in isolation from other stream protection plans prepared for the site; someone designs stormwater management practices, someone else does the grading plan, and others assemble wetland protection or other sensitive area requirements. Full integration and understanding is needed.

Another reason for poor ESC plans is that they are based on "cookie cutter" manuals. These manuals contain a collection of detailed standards and specifications, but there is little guidance on how to combine ESC practices into an effective plan. As well, few practices ever seem to be dropped from ESC manuals, even if monitoring data or maintenance experience has proven them to be inadequate. At the same time, design enhancements are often recommended to increase ESC effectiveness, but are seldom implemented. Cost-conscious designers and contractors will generally only choose to install ESC controls that are **absolutely** required.

The responsibility for developing a quality ESC Plan falls to the design engineer, and often delegated to junior engineers who possess little ESC training or experience. Given the limited resources, it is not surprising that ESC Plans are of poor quality or are lacking in quality.

Ten Elements of an Effective ESC Plan

Implementation of ESC plans can be improved. These ten elements present a comprehensive and integrated approach for achieving stream protection during construction. Only four of the elements actually involve better design and selection of ESC practices. Three of the elements emphasize non-structural techniques for erosion prevention, while the last three elements involve management techniques.

1. ***Minimize Needless Clearing and Grading.*** Some areas of a development site should never be cleared and graded, or these activities restricted. This includes stream buffers, forest conservation areas, wetlands, springs, highly erodible soils, steep slopes, and environmental areas.
2. ***Protect Waterways and Stabilize Drainage Ways.*** Streams and waterways are particularly susceptible to sedimentation. Clearing adjacent to a waterway should not be permitted, and a silt fence should be installed along the perimeter of the buffer. Existing drainage ways should be identified, as these will likely be the major routes that eroded sediments will take to reach streams and rivers. Drainage ways are also prone to erosion due to the high velocity of runoff. Erosion should be minimized.
3. ***Phase Construction to Limit Soil Exposure.*** Large areas of grading should be avoided since this maximizes erosion potential. Construction phasing, where only a portion of the site is disturbed at one time, minimizes sediment load potential.
4. ***Stabilize Exposed Soils Immediately.*** To provide soil stabilization, it is important to establish cover over the denuded area within two weeks of the soils being exposed. Covers such as grass, mulch, erosion control blankets, and plastic sheeting can be used to achieve this.
5. ***Protect Steep Slopes and Cuts.*** Steep slopes are the most highly erodible surfaces within construction sites. Steep slopes are generally defined with slopes of 6H:1V to 3H:1V or greater. Where possible, clearing and grading of steep slopes should be avoided. Otherwise, special techniques, such as uphill flow diversion and silt fencing, should be used to prevent uphill runoff from flowing down the slopes.
6. ***Install Perimeter Controls to Filter Sediments.*** Perimeter controls should be implemented at the edge of the construction site to retain or filter runoff before it leaves the site. Silt fences an earth dikes or diversion are the two most common controls.

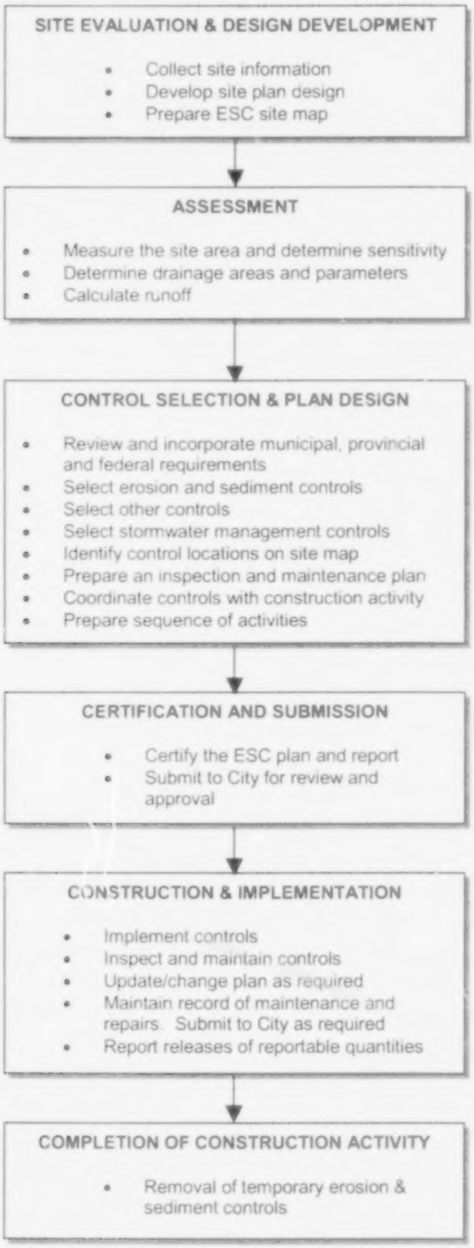
7. ***Employ Advanced Sediment Settling Controls.*** Even when the best ESC measures are employed, high concentrations of sediments may be discharged during larger storms. Therefore, the ESC plan should include some sediment traps or basins to allow captured sediments to settle out. To improve the trapping efficiency, these basins must be designed to incorporate features such as larger volumes, use of baffles, skimmers and other outlet devices, and multi-cell construction. Regular inspection and maintenance are also critical to the operation of these practices.
8. ***Ensure Contractors are Trained on ESC Plan Implementation, Inspection, Maintenance and Repairs.*** The most important element in the implementation of an ESC plan is the training and experience of the contractors, as they are usually responsible for installation and maintenance of the practices. In the end, everyone is responsible for erosion and sediment control. Therefore, training and education is important for everyone, from the developer down to the homebuilder. Everyone is working towards the same goal of protecting our waterways.
9. ***Adjust ESC Plan at Construction Site.*** For an ESC plan to be effective, it may have to be modified due to discrepancies between planned and as-built grades, weather conditions, altered drainage and unforeseen requirements. Regular inspections are needed to ensure that ESC controls are working properly. **Inspections should be conducted every one to two weeks and after larger rainstorms.**
10. ***Assess ESC Practices After Storms.*** After a rainstorm, it is usually clear whether an ESC plan worked or not. If the storm was unusually large or intense, it is likely that many of the controls will require repair, clean out, or reinforcement. Therefore a quick response to assess and correct damages of the controls is required.

9.3 Design Approach

An Erosion and Sediment Control Plan should be prepared for **all** construction projects. For Drainage & Site Servicing Plan (DSSP) sites smaller than 2 ha (5 acres), this will consist of minimum control measures known as good housekeeping practices. Good housekeeping measures should be indicated on the construction drawings. DSSP sites larger than 2 ha require the submission of an Erosion and Sediment Control Report. See **Section 9.7 Technical Requirements**. Sites smaller than 2 ha may be required to submit an Erosion and Sediment Control Report if the site is close to a receiving stream or is otherwise deemed to be in or adjacent to a sensitive area (ie. ER, ravine, etc.).

Development of an effective ESC plan is important to protecting our watercourses from sediment pollution. When developing and implementing an ESC plan, the following steps should be followed:

Figure 9.4: Erosion & Sediment Control Plan Development Process



SITE EVALUATION & DESIGN DEVELOPMENT

- Collect site information
- Develop site plan design
- Prepare ESC site map

ASSESSMENT

- Measure the site area and determine sensitivity
- Determine drainage areas and parameters
- Calculate runoff

CONTROL SELECTION & PLAN DESIGN

- Review and incorporate municipal, provincial and federal requirements
- Select erosion and sediment controls
- Select other controls
- Select stormwater management controls
- Identify control locations on site map
- Prepare an inspection and maintenance plan
- Coordinate controls with construction activity
- Prepare sequence of activities

CERTIFICATION AND SUBMISSION

- Certify the ESC plan and report
- Submit to City for review and approval

CONSTRUCTION & IMPLEMENTATION

- Implement controls
- Inspect and maintain controls
- Update/change plan as required
- Maintain record of maintenance and repairs. Submit to City as required
- Report releases of reportable quantities

COMPLETION OF CONSTRUCTION ACTIVITY

- Removal of temporary erosion & sediment controls

A number of measures can be implemented to mitigate the effects of urban development through careful planning and design. Consideration should be given to:

i. limiting development and construction to the least critical areas. Therefore, shorelines, floodplains, natural drainage ways, steep slopes, and erodible soils should be avoided where possible.
ii. efforts should be made to preserve and utilize natural drainage systems. Impervious surfaces should be minimized to enhance infiltration.
iii. alternative methods of runoff and stormwater management should be considered to enhance infiltration. This will benefit the normal stream in alleviating the need for additional stream alterations due to additional flows.

The ESC report should include both a written portion and an illustrative portion, which includes maps and details (see **Section 9.7** for technical requirements). The written portion should explain and justify the control measures chosen, and include information concerning site conditions, construction schedules, inspection and monitoring schedules, and other pertinent items not contained in the drawings. The drawings should describe where and when the various measures should be installed, the expected performance, and actions to be taken if performance goals are not achieved. The report should be a stand-alone document that can be located on the construction site for use by construction and inspection personnel. As site work progresses, the plan should be modified by the consultant and contractor to reflect changing conditions.

The ESC plan and/or report should consider 12 elements:

- Mark clearing limits
- Establish construction access
- Detain flows
- Install sediment controls
- Stabilize soils
- Protect slopes
- Protect drain inlets
- Stabilize channels and outlets
- Control pollutants
- Control de-watering
- Maintain BMPs
- Manage the project

General principles should consider the following:

(1) Prevent pollutant release. Source control BMPs should be selected as the first line of defence.
(2) Erosion and sediment control measures, or other BMPs, should be selected based on the site characteristics and the construction plan.
(3) Site drainage and soil conditions should be assessed to determine the most significant factors for the site and planned construction.
(4) Runoff should be diverted away from exposed areas when possible.
(5) Existing vegetation should be preserved.
(6) The extent of clearing and phased construction operations should be limited.

(7) Natural drainage features should be incorporated when possible. Adequate buffers should be used to protect areas where flow enters the drainage system. Keep clean water clean.
(8) Minimize slope length and steepness.
(9) Runoff velocities should be reduced to prevent channel erosion.
(10) Prevent tracking of sediment off-site.
(11) Select the appropriate control measures for control of pollutants other than sediment.

9.4 Methods

Geotechnical consultants should be consulted at the start of the project to address soil erodibility and other geotechnical issues. Once an evaluation has been carried out to determine the effects of erodibility of the site and the sensitivity of the downstream area to sedimentation, then appropriate control measures can be determined. It is important that all construction sites, big and small, employ minimum control measures.

A large number of erosion and sediment control measures are available. Therefore, the selection of specific controls is important to the overall effectiveness and success of the project. Proper selection should consider the overall site evaluation, season, construction requirements, design requirements, and cost.

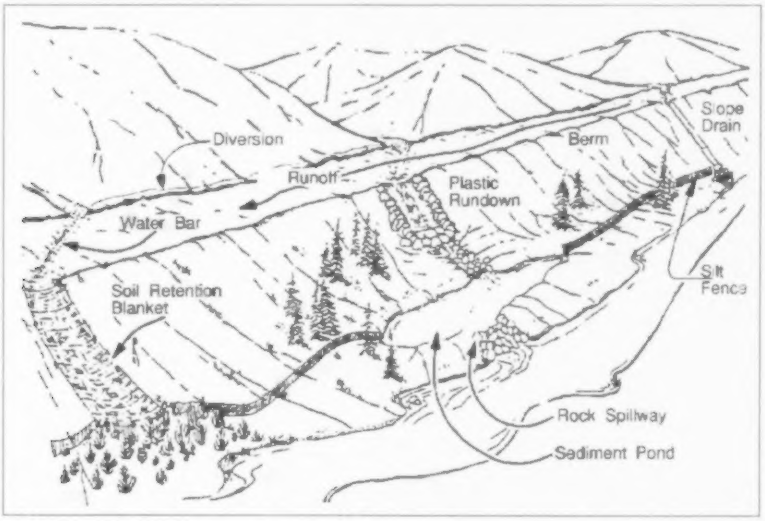


Figure 9.5: Example of Erosion and Sediment Control Features

The degree of control must also be assessed. When a site has low erosion potential and the impact on the downstream water uses is also low, good housekeeping" measures may be sufficient for erosion and sediment control. When the impact and potential for erosion is greater, then further specific control measures will be required.

Refer to Table 9.2. However, monitoring of the measures is required to determine whether the degree of control used is sufficient.

Table 9.2: Degree of Erosion and Sediment Control

Site Erosion Potential	Impact on Downstream Water Uses	Degree of Erosion and Sediment Control
Low	Negligible Yes	Good housekeeping measures only Consider sedimentation pond(s)
Moderate	Negligible Yes	Erosion and sediment controls Erosion controls and sedimentation ponds(s)
High	Negligible Yes	Erosion and sediment controls All flows to on-site sedimentation pond(s)

There are many erosion and sedimentation concerns that arise due to construction activities. These include, but are not limited to the following:

- mud tracking from construction sites onto adjacent properties and streets
- silt and debris washed into the existing storm sewer (or drainage) system
- silt and debris transported to receiving watercourses by surface runoff and the sewer system
- wind blown dust during dry weather

However, good housekeeping, erosion and sediment control practices can be employed during construction to minimize and/or eliminate these concerns.

9.4.1 Good Housekeeping Practices

Good housekeeping practices will help minimize some of the erosion and sediment concerns. While some may be impractical under certain conditions, others should be considered based on suitability, practicality and cost effectiveness.

1) Dust control measures should be implemented to prevent wind transport of dust from disturbed soil surfaces. This may be accomplished several ways. Vegetate or mulch areas that won't receive vehicle traffic. Otherwise, construct wind breaks or screens. The site may also be sprinkled with water or a chemical dust suppressant to control dust; however, care must be taken to prevent the tracking of mud that may result. Another effective tool is to reduce vehicle speed limits to decrease the amount of dust stirred up from unpaved roads and lots.

2) Stockpiles should be located away from watercourses, environmentally sensitive areas, drainage courses, ravines, and existing adjacent developments. The stockpiles should be stabilized against erosion immediately following stripping operations.

Stabilization can include, but is not limited to, establishment of a cover crop.

3) All construction vehicles should leave the site at a designated point or points. Gravelling or paving of frequently used access roads will help ensure that minimal material such as mud is tracked off-site. In situations where mud tracking becomes a major problem, a washdown facility for truck wheels should be considered.

4) When sewers have been installed or are existing, measures should be undertaken to ensure sediment and debris does not get into the municipal sewer system. Both catchbasins and manholes should be protected. This may be accomplished by sealing the openings, setting up sumps or weirs inside the structures, or by providing appropriate inlet protection (filter fences, sediment traps, etc.).

5) Temporary and permanent storage facilities for sedimentation should be considered prior to the commencement of earth moving activities.

6) All accumulated sediment and debris should be removed as required. Once construction activities are complete, all related materials and temporary structures should be removed and properly disposed of.

9.4.2 Erosion Control

Erosion controls are surface treatments that stabilize soil exposed by grading or excavation. Erosion control measures, also commonly referred to as Best Management Practices (BMPs), typically include source controls, vegetative controls and non-structural controls. For more information and specific details, refer to the City of Calgary's "**Guidelines for Erosion & Sediment Control**".

Choosing the right erosion control can be confusing and difficult given the wide range of techniques available. Too often, the cost alone determines the erosion control method used. While cost is an important consideration, other factors related to the site should be considered. This includes soil quality, climate, flow velocities and construction activity. In many circumstances, covering the ground as quickly as possible provides the best means of erosion control. Options are available to provide cover during critical periods. This can include mulch, erosion control blankets, and plastic sheeting.

An effective erosion and sediment control strategy is directed towards preventing sediment loss through protection of exposed surfaces and the control of runoff (see Table 9.3). The movement of sediment-laden stormwater is not necessarily a concern if the flow does not leave the site.

Table 9.3: Erosion Control Measures

(ADAPTED FROM MICHIGAN DEPARTMENT OF NATURAL RESOURCES 1980)

NAME			APPLICABILITY							COMMENTS	SUGGESTED AS A MINIMUM MEASURE?
			SLOPES	STREAMS AND WATERWAYS	SURFACE DRAINAGEWAYS	ENCLOSED DRAINAGE (INLET/OUTLET)	LARGE FLAT SURFACE AREAS	BORROW AND STOCKPILE AREA	ADJACENT PROPERTIES		
PROTECTION OF EXPOSED SURFACES	VEGETATIVE	SEEDING	•		•		•	•	•	INEXPENSIVE AND VERY EFFECTIVE. STABILIZES SOIL, THUS MINIMIZING EROSION. PERMITS INFILTRATION WHICH REDUCES RUNOFF VOLUME. SHOULD INCLUDE PREPARED TOPSOIL BED.	YES
		MULCHING	•			•	•			USED ALONE TO PROTECT EXPOSED AREAS FOR SHORT PERIODS. PROTECTS SOIL FROM RAINSPLASH. PRESERVES SOIL MOISTURE AND PROTECTS GERMINATING SEED FROM TEMPERATURE EXTREMES.	YES
		SEEDING WITH MULCH	•		•			•	•	FACILITATES ESTABLISHMENT OF VEGETATIVE COVER. EFFECTIVE FOR DRAINAGE WAYS WITH LOW VELOCITY. EASILY INSTALLED ON A SMALL SCALE BY INEXPERIENCED PERSONNEL. SHOULD INCLUDE TOPSOIL BED.	YES
		HYDRO-SEEDING	•				•	•	•	EFFECTIVE ON LARGE AREAS. MULCH TACKING AGENT USED TO PROVIDE IMMEDIATE PROTECTION UNTIL GRASS IS ROOTED. SHOULD INCLUDE PREPARED TOPSOIL BED.	YES
		SODDING	•		•		•	•	•	PROVIDES IMMEDIATE PROTECTION. CAN BE USED ON STEEP SLOPES. EASY TO PLACE. MAY BE REPAIRED IF DAMAGED. SHOULD INCLUDE PREPARED TOPSOIL BED.	YES
	NON VEGETATIVE	RIP-RAP/RUBBLE/GABIONS	•	•	•					USED WHERE VEGETATION NOT EASILY ESTABLISHED. EFFECTIVE FOR HIGH VELOCITIES OR CONCENTRATIONS. PERMITS INFILTRATION. DISSIPATES ENERGY OF FLOW OF SYSTEM OUTLETS.	
		AGGREGATE COVER					•			STABILIZES SOIL SURFACE THUS MINIMIZING EROSION. PERMITS CONSTRUCTION TRAFFIC IN ADVERSE WEATHER. MAY BE USED AS PART OF PERMANENT BASE CONSTRUCTION OF PAVED AREAS.	YES
		PAVING	•				•			PROTECTS AREAS WHICH CANNOT OTHERWISE BE PROTECTED, BUT INCREASES RUNOFF VOLUME AND VELOCITY. IRREGULAR SURFACE WILL HELP SLOW VELOCITY.	
CONTROL OF RUNOFF		SELECTIVE GRADING AND SHAPING	•				•	•	•	WATER CAN BE DIVERTED TO MINIMIZE EROSION. FLATTER SLOPES EASE EROSION PROBLEMS.	YES
		ROUGHENED SURFACE	•				•			REDUCES VELOCITY AND INCREASES INFILTRATION RATES. COLLECTS SEDIMENT. HOLDS WATER, SEED AND MULCH BETTER THAN SMOOTH SURFACES.	YES
		BENCHES	•					•		REDUCES RUNOFF VELOCITY BY REDUCING EFFECTIVE SLOPE LENGTH. COLLECTS SEDIMENT. PROVIDES ACCESS TO SLOPES FOR SEEDING, MULCHING AND MAINTENANCE.	YES
		ROCK/STRAWBALE DIVERSION BERM	•					•	•	DIVERTS WATER FROM VULNERABLE AREAS. COLLECTS AND DIRECTS WATER TO PREPARED DRAINAGE WAYS. MAY BE PLACED AS PART OF NORMAL CONSTRUCTION OPERATION.	YES
		DIVERSION DITCH	•					•	•	COLLECTS AND DIVERTS WATER TO REDUCE EROSION POTENTIAL. MAY BE INCORPORATED IN PERMANENT PROJECT DRAINAGE SYSTEMS.	
		ENERGY DISSIPATOR	•		•	•				SLOWS RUNOFF VELOCITY TO NON-EROSIVE LEVEL. PERMITS SEDIMENT COLLECTION FROM RUNOFF.	

9.4.2.1 Protection of Exposed Surfaces

The erosive energy of raindrop splash and overland flows needs to be considered when selecting appropriate erosion control measures. The use of temporary or permanent vegetative and non-vegetative cover will help provide protection of exposed surfaces.

Vegetative Cover

Vegetative cover can include seeding, mulching, hydro-seeding or sodding, or a combination of these.

i. Seeding

Seeding is typically done with annual or perennial grasses and legumes. Often fertilizer and mulch/tackifier are applied immediately afterwards to aid in establishing cover. Seeding can provide long-term stabilization of disturbed areas and is relatively low cost. However, seeding should only be undertaken during or immediately before the growing season. Seeding will not provide immediate cover and bare soil will persist until the plants have taken hold. Seeding should be confined to flat areas and on slopes less than 3H:1V. When loam piles are left for long periods of time seeding can also help control weeds

ii. Mulching

Mulching refers to the application of organic material or other suitable substances to the soil surface to conserve soil moisture and help establish plant cover. Mulching may also prevent surface compaction, reduce runoff and surface erosion, and control weeds. Long-term and short-term erosion control can be accomplished with mulching.

Mulch mixtures should be based on the type of soil to be protected, site conditions, season, costs and the availability of labour, equipment and materials. Organic mulches include straw, raw wood fibre, peat moss, wood chips, bark, pine needles, compost and verdyol. Chemical mulches are also available and include a wide range of synthetic spray-on materials. These can be emulsions or dispersions of vinyl compounds, asphalt, rubber, or other water-based substances.

iii. Hydro-Seeding

Hydro-seeding involves the application of a slurry containing annual or perennial seeds, fertilizer, mulch, soil adhesive and water. The slurry is then sprayed on the area to be revegetated. Steep rocky or gravely slopes can be revegetated with hydro-seeding; it can also be used in areas where seeding or sodding is applied. Care should be taken when considering the materials to be used in the hydro-seeding mixture. Success of the application will depend of adequate knowledge of site conditions such as soil drainage, texture and pH.

iv. Sodding

The use of permanent grass sod can also be used to cover and stabilize disturbed areas, particularly in areas where complete cover is immediately required or where seeding is not practical. (ie. drainage ways). Sod is best used where adequate topsoil or fertilizer and water can be provided for establishment. The surface must be graded relatively smooth and free of debris, large stones, trash and other large objects; otherwise the sod roots will not take hold. Freshly laid sod will require irrigation to moisten the soil for rooting.

v. Chemical Stabilization

Chemical substances, or stabilizers, may also be used to change the properties of the soil surface, generally by aggregating the finer soil particles. The stabilizers may be used in place of mulch materials, or in combination with mulch materials. Chemical soil stabilizers can be used to protect exposed soil slopes or in areas where the use of vegetation as a soil stabilizer is not possible. The stabilizers work best on dry highly permeable soils, or on in-place soils subject to sheet flow rather than concentrated flow. Long-term protection may be difficult to achieve; therefore, this method should be considered only temporary.

vi. Trees and Shrubs

Trees and shrubs can be used to cover and stabilize disturbed areas as well as prevent the initiation of erosion. They form a canopy above the ground that protects the soil surface from the full impact of rainfall and winds. If the stands are well established, there may be a layer of organic material on the ground that increases the absorption capacity of the soil. However, the roots of trees and shrubs are not as effective as grass roots in holding topsoil in place. Unfortunately, time is needed to establish good cover, and planting is usually expensive. Trees and shrubs may be used to protect graded or cleared areas where a permanent vegetation is wanted. They are best used on steep or rocky slopes where moving is not feasible, in shady areas where other types of vegetation species experience difficulty, and where forestry, landscaping and wildlife features are desired.

Non-Vegetative Cover

Non-vegetative cover can include rip-rap, gabions, aggregate cover and paving.

i. Rip-Rap

Rip-rap provides a durable erosion-resistant ground cover that protects the soil surface from erosive forces, slows runoff velocity, and stabilizes slopes. Stone rip-rap is the most popular material used since it is durable, heavy and flexible (rip-rap adjusts to changes resulting from erosion beneath the stones). The most common locations for rip-rap are stream channel banks, slopes of dikes, inlet and outlet structures, and bridge abutments. Rip-rap should be placed before runoff has an opportunity to create erosion. Filter fabrics or blankets may also be used to separate the soil from the rip-rap, redistribute forces acting on the soil, and provide drainage facilities.

ii. Aggregate Cover

Aggregate cover includes the use of crushed stone or gravel applied directly to the soil surface. The aggregate stabilizes the soil, and therefore reduces erosion potential. Aggregate cover may be used to stabilize soils impacted by construction traffic, in wet areas or on slopes. It is also suitable for areas where ground water emerges through the surface of the soil.

iii. Nets and Matting

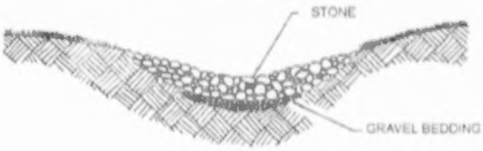
Nets, matting and blankets can be placed on the ground surface to stabilize the soil. Materials include jute, twisted paper mesh, fibreglass, cotton, finely woven plastics, excelsior and woven metal wires, as well as other natural and synthetic products. Staples are typically used to hold the mats in place. Mats are suitable for use on level areas, in waterways, or on slopes. Primary use is on steep slopes where newly established vegetation requires protection. The mats help reduce runoff high velocities. When used in combination with mulch materials, the mats act as an anchor that binds the mulch material and prevents wind blow.

9.4.2.2 Control of Runoff

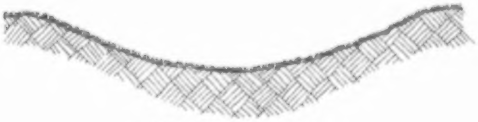
During construction it is not always possible or practical to provide surface cover for disturbed areas. By modifying the slope surface, reducing slope gradients, controlling runoff velocities, diverting flows around the affected area, and providing upstream storage, the ground surface can be protected.

i. Grassed Waterways

Grassed waterways are broad shallow channels that are designed and constructed to carry concentrated surface runoff to a drainage outlet. The channels are stabilized with herbaceous vegetation such as grass. Although waterways can be designed to accommodate various grades, the channel bottom should be constructed with relatively shallow grades of about 1% so runoff is conveyed slowly. The vegetation in the channel restricts the flow, thereby resisting soil erosion. The outlet of the channel should also be stabilized to prevent erosion.



WITH STONE CENTRE



WITHOUT STONE CENTRE

Figure 9.6: Grassed Waterways

Regular maintenance is important to keep the waterway in good working condition. Bare and eroded spots should be quickly seeded or re-sodded. Mowing and spraying for weed control should be done on a regular basis.

ii. Stormwater Channels and Ditches

Stormwater channels are designed to safely convey excess stormwater runoff from a developing area. The channels are lined with vegetation or structural material to prevent erosion. Capacity of the channel should be carefully considered in the design.

Open ditches are usually less expensive to install than other types of drains and inspection is easy. However, the maintenance costs can exceed the cost of other types of installations.

iii. Construction Roads and Parking Areas

Construction roads and parking areas will require temporary stabilization to reduce erosion and sedimentation potential. Where possible, temporary roads should follow the contour of the natural terrain. Temporary parking areas should be located on flat areas but should be graded to provide drainage. A layer of aggregate should be applied to provide stabilization. Periodic maintenance will be required.

9.4.3 Sediment Control

Sediment controls capture soil that has eroded. While the prevention of initial erosion should be the primary goal, some sediment on construction sites cannot be entirely eliminated. To complement erosion control practices, some form of sediment control should be employed. Generally this can be achieved through filtration of the sediment laden flows, or by impounding the flows to allow settling. Sediment control measures are also commonly referred to as Best Management Practices and include several structural and non-structural controls. For more information and specific details, refer to the City of Calgary's "**Guidelines for Erosion & Sediment Control**".

Effective sediment control is achievable through several methods. Some of these are outlined in Table 9.4.

9.4.3.1 Filtering

Soil particles suspended in runoff can be filtered through porous media consisting of natural and artificial materials (ie. vegetative strips, stone filters, man-made fibre filters). Filtering can be effectively applied to concentrated channels flows at inlets of permanent or temporary drainage systems. However, filtering is most effective when applied to sheet flow from a wide area; a line adjacent to the flow at either the top or toe of an embankment slope will provide sufficient filtering action.

The most commonly used filtering methods are straw bales or silt curtains. These methods should only be used when there is a small amount of runoff. Otherwise, effectiveness decreases. As well, straw bales are only moderately effective in trapping medium and coarse grained sediment; trapping of fine-grained sediment is generally ineffective. Silt fences and curtains are more effective for trapping all particle sizes, depending on the mesh size used. Straw bales and silt fences should be structurally sound.

Table 9.4: Sediment Control Measures

(ADAPTED FROM MICHIGAN DEPARTMENT OF NATURAL RESOURCES 1980)

	NAME	APPLICABILITY							COMMENTS	SUGGESTED AS A MINIMUM MEASURE?
		SLOPES	STREAMS AND WATERWAYS	SURFACE DRAINAGEWAYS	ENCLOSED DRAINAGE (INLET/OUTLET)	LARGE FLAT SURFACE AREAS	BORROW AND STOCKPILE AREA	ADJACENT PROPERTIES		
FILTERING VEGETATIVE	VEGETATIVE BUFFER STRIP	•	•					•	SLOWS RUNOFF VELOCITY. FILTERS SEDIMENT FROM RUNOFF. REDUCES VOLUME OF RUNOFF ON SLOPES.	YES
	FILTER BERM	•	•					•	CONSTRUCTION OF GRAVEL OR STONE. INTERCEPTS AND DIVERTS RUNOFF TO STABILIZED AREAS OR PREPARED DRAINAGE SYSTEM. SLOWS RUNOFF AND COLLECTS SEDIMENT.	YES
	STRAWBALE/ROCK FILTER			•	•			•	INEXPENSIVE AND EASY TO CONSTRUCT. CAN BE LOCATED AS NECESSARY TO FILTER SEDIMENT FROM RUNOFF. STRAWBALES MAY BE USED IN CONJUNCTION WITH SNOW FENCE.	YES
	SOD FILTER			•	•				INEXPENSIVE AND EASY TO CONSTRUCT. PROVIDES IMMEDIATE PROTECTION. PROTECTS AREAS AROUND INLETS FROM EROSION.	YES
	BRUSH FILTER			•	•				USES SLASH AND LOGS FROM CLEARING OPERATIONS. CAN BE COVERED AND SEEDED RATHER THAN REMOVED. ELIMINATES NEED FOR BURNING OR REMOVAL OF MATERIAL FROM SITE.	YES
	SILT FENCE	•		•	•			•	FILTERS SEDIMENT FROM RUNOFF AND ALLOWS WATER TO POND AND SETTLE SEDIMENT.	
IMPOUNDMENT	STRAWBALE/SANDBAG/ EXCAVATED/SEDIMENT TRAP/ SEDIMENT POND		•	•					MAY BE CONSTRUCTED OF A VARIETY OF MATERIALS. COLLECTS AND TRAPS SEDIMENT AND REDUCES VELOCITY OF FLOW. CAN BE CLEANED AND EXPANDED AS NEEDED.	

i. Vegetative Buffer Strip

Strips of dense vegetation can be used to prevent erosion and sedimentation between disturbed areas and sensitive areas. Sediment, organic matter and other pollutants are removed from runoff through filtration and absorption. A strip of trees or shrubs can also provide a windbreak to reduce wind erosion. Vegetated buffer strips are densely vegetated bands consisting of grasses, vines, shrubs and trees. They are usually oriented perpendicular to the direction of sediment flow. The strips may be used to protect property boundaries, steep slopes, surface water such as receiving streams, and other areas sensitive to sediment accumulation.

ii. Straw Bale Filters, Rock Filters and Brush Barriers

Filters in general remove sediment and reduce runoff velocity. They can be constructed from any stabilized porous media such as straw bales or crushed rock. There is no predetermined shape for filters. However, it is important that runoff flow through the filter rather than around it.

Filters may be used around drain inlets, along the toes of slopes, on small slopes, on sediment basin dams, between water bodies and next to adjacent downhill properties. The filters should be used where there is an existing drainage system and for relatively small drainage areas.

Straw bales may be used as filters and are relatively inexpensive. They provide an effective but temporary barrier but only have a life expectancy of three months. During installation, it is important that the strawbales are imbedded into the soil with ends tightly abutting adjacent strawbales.

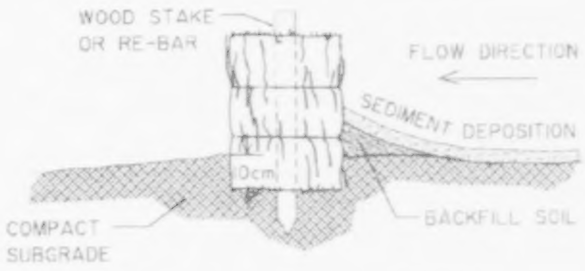


Figure 9.7: Strawbale Filter

Filters that use rock as the filtering media have a longer life expectancy than strawbales. However, construction and repair of rock filters may not be as simple since the rocks do not generally hold together as well. Rock filter media should be composed of clean, hard, durable particles free of organic matter, clay, or other material that would interfere with filtering capacity. Rock filters can be constructed in a form similar to check dams.

Brush barriers are used as temporary filters. The barrier is constructed by piling brush, stone and root mats into a mounded row. During clearing operations, a mixture of tree limbs, small vegetation, roots and small amounts of soil and rock can be made into windrows along the toe of a slope.

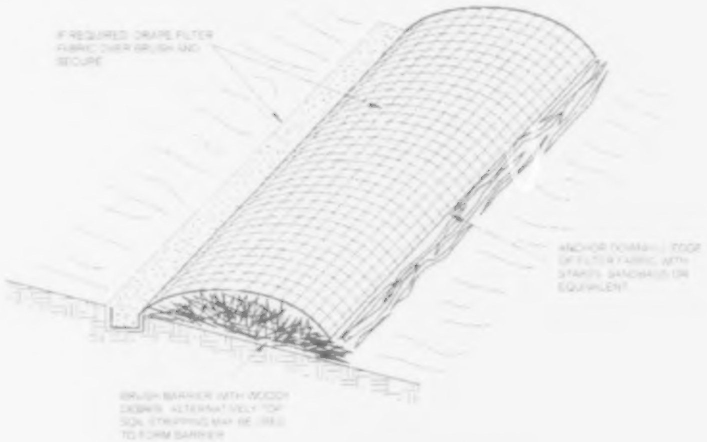

IF REQUIRED, DRAPE FILTER FABRIC OVER BRUSH AND SECURE
ANCHOR DOWNHILL EDGE OF FILTER FABRIC WITH STAKES, SANDBAGS OR EQUIVALENT
BRUSH BARRIER WITH WOODY DEBRIS. ALTERNATIVELY TOP SOIL STRIPPING MAY BE USED TO FORM BARRIER

Figure 9.8: Brush Barrier

iii. Check Dams

Check dams are used to prevent channel erosion by reducing runoff velocity, lengthening detention time, and increasing the cross-sectional are of the runoff stream. The structures may be made of stones, concrete, metal, gabions, wood (logs) or other materials. Strawbales are susceptible to washouts and are not recommended.

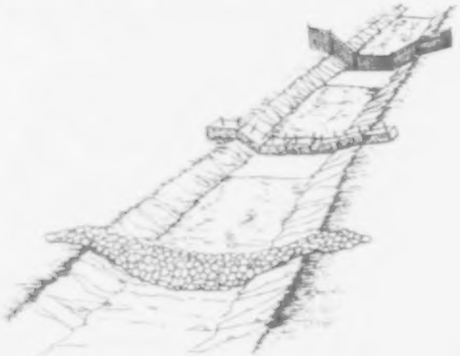


Figure 9.9: Rock, Strawbale and Silt Fence Check Dams

The check dam is constructed across the channel, perpendicular to the contours and direction of flow. Check dams are used when vegetative measures are not sufficient to handle runoff velocities, in areas of excessive slope conditions, or where runoff must travel from a higher elevation to a lower elevation.

iv. Silt Fence

A silt fence is a sediment barrier that uses standard or extra strength filter fabric attached to a support fence. Silt fences slow runoff flows and act as a filter to remove suspended sediment. They are most effective when used to control sediment below disturbed areas where sheet or rill erosion occurs.

Silt fence fabric is composed of both natural and synthetic materials. Woven and non-woven fabrics are available commercially with the woven fabrics generally having higher strength. Due to the variability in permeability of the material, there can be considerable differences in filtering capacities for finer silt and clay particles.

The height of a silt fence should not exceed 1 m so as not to impound dangerously large quantities of water. The bottom of the silt fence should be firmly anchored in the soil for best filtering results. As well, a silt fence should be considered as a temporary barrier with a usable life span of about six months.

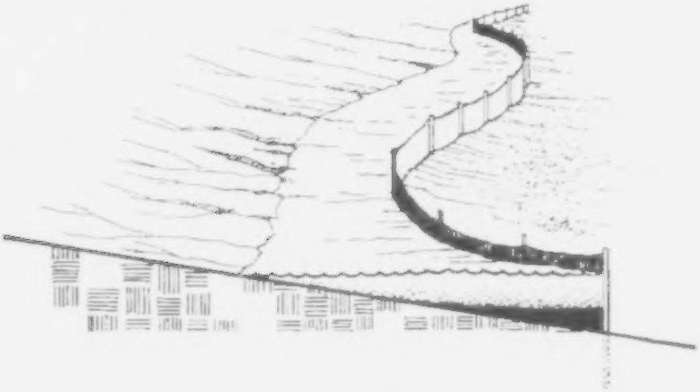


Figure 9.10: Silt Fence

9.4.3.2 Impoundments

Impoundment of sediment-laden runoff permits the settling of suspended sediments. The impoundments or traps may be formed through excavation, above ground embankments, or a combination of both. Earth, stone, strawbales, and silt fencing can be used to construct the traps. If properly constructed and well maintained, sediment traps are an effective method to minimizing the transport of sediment off-site. Care should be taken when designing significant embankments, since these may have to be designed to small dam standards.

i. Sediment Traps and Ponds

Sediment traps and ponds should be located in areas where sediment-laden runoff can be slowed in velocity prior to entering a drainage inlet, allowing sediment to settle out. Release rates from the ponds are controlled. The sediment traps are temporary settlings ponds that use a spillway with an outlet structure simple. Overall, they are simple and relatively inexpensive to install. They are most effectively used where drainage swales enter the sewer system or receiving water.

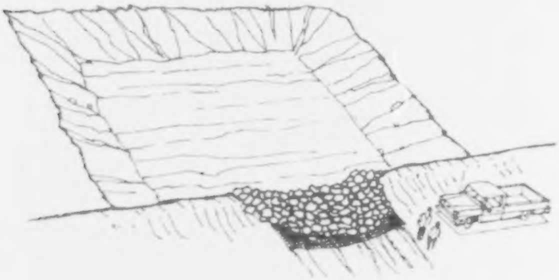


Figure 9.11: Sediment Trap/Pond

Use of check dams is also a form of sediment traps, as is the use of sandbags in natural waterways that create small dams. Sod, strawbales, rock or other filters can be used around catchbasins and drainage inlets to form sediment traps. Sumps inside catchbasins and manholes can also be set up temporarily with the use of weirs. Sediment accumulation should be monitored; sediment should be removed when accumulation reaches about one half the height of the sump, weir, or filter barrier.

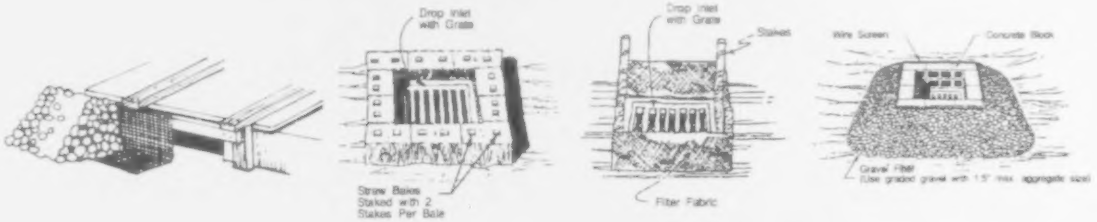

Drop Inlet with Grate
Straw Bales Staked with 2 Stakes Per Bale
Drop Inlet with Grate
Stakes
Filter Fabric
Wire Screen
Concrete Block
Gravel Filter
(Use graded gravel with 1.5" max. aggregate size)

Figure 9.12: Types of Inlet Protection

9.5 Temporary Measures vs Permanent Measures

Sediment and erosion control measures can typically be divided into two groups:

- **Temporary** measures which are used only during the construction phase, and
- **Permanent** measures which are intended for permanent use and should be incorporated into the overall design of the development

Temporary erosion and sediment control measures are typically constructed during the construction phase. The purpose of these temporary measures is to prevent the transport of sediment to streams, wetlands, lakes, drainage systems and adjacent properties. These measures can include but are not limited to: buffer strips, filters (strawbale, rock or brush), and sediment traps and ponds.

There are a number of permanent structures that can be incorporated for the long-term control of runoff. These structures would not be removed after construction completion but would become part of the overall site stormwater plan through integration into the urban design. These permanent structures include the following:

Wet Ponds and Extended Detention Ponds

Wet ponds can be used to accept additional stormwater runoff from construction activities to reduce downstream erosion and to trap sediments and contaminants. The pond drains must allow the excess water to drain slowly. A number of variations to the basic design could be used ranging from relatively small single basins to multiple interconnected basins. Regular maintenance involving sediment removal would be required to ensure that adequate capacity and drainage is maintained.

Extended detention ponds would allow runoff to be detained through slow release rates. Detention allows the sediment to settle out. Due to the slow release, these ponds are generally designed to be dry between runoff events. However, clogging of the outlet is the main concern due to the slow release rate. Therefore, the outlet should be protected or designed accordingly.

Infiltration Basins and Trenches

These structures are designed to impound water for the purpose of enhancing infiltration. The basins are typically dry. While the ability to trap sediment is high, the life of the structure may be short-lived due to the potential for rapid clogging. A high level of maintenance is required to maintain these structures.

Grassed Swales

Grassed swales act as conveyance channels which enhance sediment removal and increase infiltration. By increasing detention time over the length of the swale (through check dams), sediment removal can be enhanced.

Filter Strips

Filter strips are usually vegetated strips that buffer the development site and the waterway. The strips are generally flat and provide sediment reduction by overland runoff flowing over the strips. However, proper maintenance is required to ensure effective treatment.

Wetlands

Constructed wetlands can also be used for interim sediment removal. The shallow pools provide a suitable growing condition for marsh plants, which in turn provides sediment and pollutant removal through uptake, retention and settling. Periodic maintenance is required to remove accumulated sediments. The use or modification of natural wetlands should not be used.

9.6 Monitoring and Maintenance

All temporary and permanent erosion and sediment control measures shall be inspected, maintained and repaired by the developer/owner, or an appointed designate, during the construction phase as needed to ensure continued performance. **As a minimum, all construction sites should employ good housekeeping practices (see Section 9.4.1).**

9.6.1 Inspections

All erosion and sediment controls must be inspected every 7 days and following heavy rainstorms or snowmelt events. All disturbed areas of the site, material storage areas, entrance and exit roads, and **all** erosion and sediment controls must be inspected. The controls must be in good operating condition until the area they protect has been completely stabilized and the construction activity complete. Inspection is the responsibility of the developer/owner or his designate, which could be the contractor and/or consultant. Inspection procedures may vary depending on the season (ie. spring/summer compared to fall/winter). To enhance knowledge and understanding, the City of Calgary will endeavour to provide ESC training for contractors, builders, consultants, and developers on a regular basis. The developer/owner, or designate, must ensure compliance to regulatory requirements.

Pursuant to sections 99 and 100 of the Environmental Protection and Enhancement Act, releases of substances that cause or may cause an adverse affect on the environment must be reported. Release of substances includes sediment-laden runoff from construction sites. Reporting is required under the provincial Release Reporting Regulation (117/93).

9.6.2 Maintenance and Repairs

Maintenance and repair of the control measures are the responsibility of the developer/owner, or the appointed designate. A schedule of planned maintenance activities is required with the submission of the Erosion and Sediment Control Plan and report and should be followed. **When implemented controls are insufficient or not working properly, changes to the ESC Plan and Report must be made to ensure continued compliance.**

Some measures such as strawbale barriers, silt fences and inlet protection devices will require periodic replacement and removal of accumulated sediment. Sediment basins (traps and ponds) will require periodic sediment removal when the design storage level is one third to one half full.

Damage or deficiencies to control measures should be corrected as soon as practicable after an inspection, but in no case later than 7 days after the inspection.

9.6.3 Records

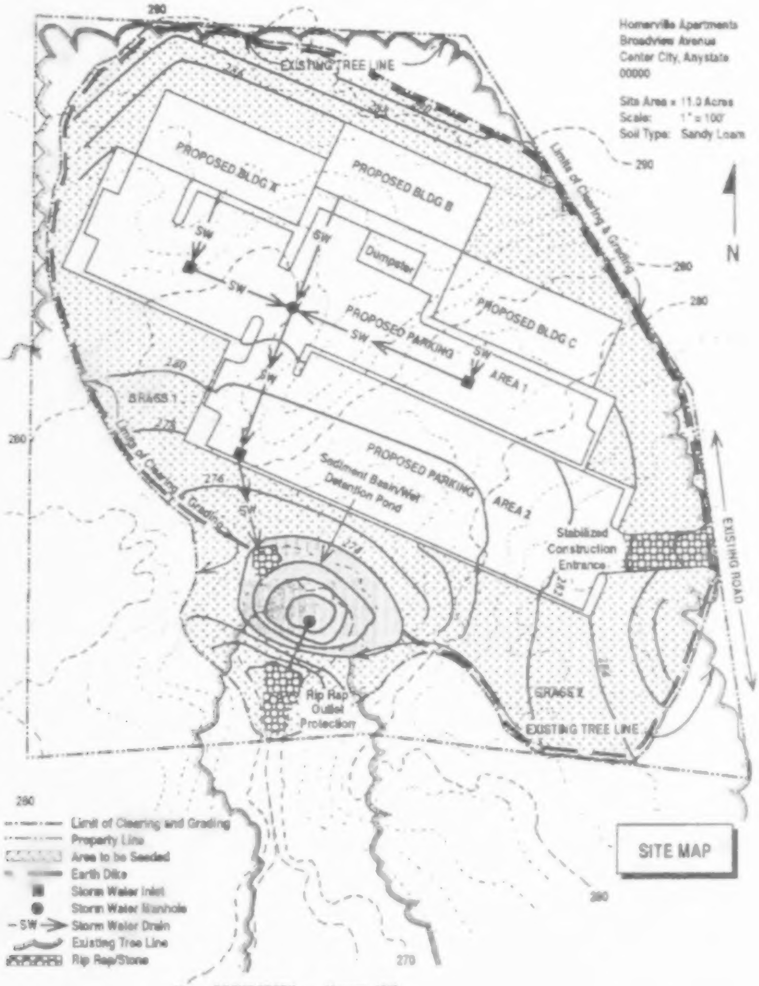
The developer/owner, or his designate, must maintain an inspection record of any maintenance, damages or deficiencies of erosion and sediment control measures. An inspection and report must be undertaken every 7 days and following heavy rainstorms or snowmelt events. The same document can be used to record maintenance and repairs undertaken after the inspection. It is the responsibility of the developer/owner, or designate, to design and implement the inspection and maintenance record. The record must be signed by the developer's/owner's inspector and must be available for review by the City's inspectors at any time. ***Failure to complete inspection/maintenance record(s), follow erosion and sediment control practices, or adequately maintain ESC controls, will require bi-weekly submission of the inspection and maintenance record to the City's Development Inspector for review.*** Also refer to **Section 9.7.1.3**.

9.7 Technical Requirements

9.7.1 Reports

i. An Erosion and Sediment Control Plan should be prepared for **all** construction projects. For sites smaller than 2 ha (5 acres), this will consist of identifying minimum control measures known as good housekeeping practices, and where practicable, implementing erosion and sediment controls to control runoff on-site. Sites larger than 2 ha require the submission of an Erosion and Sediment Control Report. During construction, the plan should be modified as required to suit field conditions and changing variables.

Figure 9.13: Example of Erosion & Sediment Control Plan


Homerville Apartments
Broadview Avenue
Center City, Anystate
00000
Site Area = 11.0 Acres
Scale: 1" = 100'
Soil Type: Sandy Loam
N
EXISTING TREE LINE
PROPOSED BLDG A
PROPOSED BLDG B
PROPOSED BLDG C
Dumpster
SW
PROPOSED PARKING
AREA 1
AREA 2
GRASS 1
GRASS 2
Limits of Clearing & Grading
Sediment Basin/Wet Detention Pond
Stabilized Construction Entrance
EXISTING ROAD
Rip Rap Outlet Protection
EXISTING TREE LINE
SITE MAP
280
290
270
Limit of Clearing and Grading
Property Line
Area to be Seeded
Earth Dike
Storm Water Inlet
Storm Water Manhole
SW Storm Water Drain
Existing Tree Line
Rip Rap/Stone
ROCKY CREEK (Approx. 450')

ii. The ESC Report should include both a written portion and an illustrative portion, which includes maps and details. The written portion should explain and justify the control measures chosen, and include information concerning site conditions, construction schedules, inspection and monitoring schedules, and other pertinent items not contained in the drawings. The drawings should describe where and when the various measures should be installed, the expected performance, and actions to be taken if performance goals are not achieved. A schedule of planned maintenance activities should also be included. A copy of the report, along with a copy of the construction drawings, should be located on the construction site for use by construction and inspection personnel. As site work progresses, the ESC Plan should be modified by the contractor to reflect changing conditions. Refer to **Appendix H Minimum Requirements for Erosion & Sediment Control Reports**.

iii. An inspection, maintenance and repair record(s) should also be kept at the construction site for review by construction personnel, inspectors, consultants and developers/owners. If erosion and sediment control practices are not being followed, or maintenance and/or repair of ESC controls is being neglected, then the record must be submitted bi-weekly to the City's Development Inspector for review.

9.7.1.1 Subdivision

For construction sites larger than 2 ha, an Erosion & Sediment Control Plan and Report must be developed and submitted to The City of Calgary Urban Development Department (Development Inspector) to obtain a stripping and grading permit. Wastewater & Drainage will further review the report. Refer to **Appendix H** for report requirements. The plan may be modified to suit changed site conditions and effectiveness.

9.7.1.2 Drainage & Site Servicing Plan

Site servicing plans refer to all commercial, industrial and multi-family parcels. For construction sites larger than 2 ha, an Erosion & Sediment Control Plan and Report must be developed and submitted to The City of Calgary Urban Development Department (Development Inspector) to obtain a stripping and grading permit. Wastewater & Drainage will further review the report. Refer to **Appendix H** for report requirements. The plan may be modified to suit changed site conditions and effectiveness.

For sites smaller than 2 ha, good housekeeping practices must be identified and employed, and where practicable, erosion and sediment controls must be implemented to control runoff on-site (see **Sections 4.13 and 9.4.1**). While an Erosion & Sediment Control report is not required, erosion and sediment control details must be provided on the drawings for review and approval.

9.7.1.3 Maintenance and Repairs

The developer/owner, or his designate, must maintain an inspection record of any maintenance, damages or deficiencies of erosion and sediment control measures. An inspection and report must be undertaken every 7 days and following heavy rainstorms or snowmelt events. The same document can be used to record maintenance and repairs undertaken after the inspection. It is the responsibility of the developer/owner to design and implement the inspection and maintenance record. The record must be signed by the developer's/owner's inspector and must be available for review by the City's inspectors at any time. ***Failure to complete inspection/maintenance record(s), follow erosion and sediment control practices, or adequately maintain ESC controls, will require bi-weekly submission of the inspection and maintenance record to the City's Development Inspector for review.***

9.7.2 Construction Drawings

A copy of the Erosion & Sediment Control Plan (drawing) and pertinent details must be included in the Construction Drawing set (preliminary and final sets) for all subdivisions and Drainage & Site Servicing Plans. This is to ensure that the ESC information is readily and easily accessible to all personnel, including inspectors and contractors. Erosion and sediment control is everyone's responsibility.

10.0 Operating, Maintenance and Monitoring Requirements

10.1 General

10.1.1 History

In the past, stormwater management consisted of the construction of stormwater systems that were designed to emphasize conveyance and flood control. Stormwater ponds would typically be designed to shave off the "peak" of the rainstorm and sediment removal was a secondary consideration, if it was considered at all. Stormwater in the ponds was usually detained for a relatively short period of time, thereby limiting the degree of water quality enhancement provided.

The introduction of water quality in stormwater management has changed the focus for design, operations and maintenance. Sediment removal maintenance is now an important consideration since sedimentation is a primary design criteria for water quality. Nutrient loading will play an increasingly major role.

10.1.2 Need for Maintenance

There are a number of operation and maintenance activities that must be carried out if a stormwater management system is to function properly. **Generally, it is the lack of proper maintenance that will cause a system to fail or result in great expense and inconvenience to the public.** Operation and maintenance go hand-in-hand in ensuring stormwater systems function properly.

Maintenance can generally be divided into preventive and corrective activities.

Preventive Maintenance

Preventive maintenance is scheduled maintenance that includes the inspection of the system, record keeping, regular maintenance and the analysis of data related to past complaints and problems. Video inspection should be carried out as required and may be reflected by historical maintenance problems, age of the system, or operational parameters such as discharge rates or water quality. Record keeping is essential to maintain a useful database.

Corrective Maintenance

Corrective maintenance is unscheduled and typically relates to emergency situations. Corrective maintenance includes the immediate repair of pipe breaks, collapses or washouts. Corrective actions can reduce flood potential, limit liability, prevent personal injury or protect the environment.

10.1.3 Responsibilities

Maintenance is a **shared** responsibility between The City of Calgary and the developers. During the required maintenance period (prior to Final Acceptance Certificate (FAC)), the developer is responsible for operation and maintenance. However, Wastewater & Drainage will respond to monitoring system alarms and spills (including hazardous spills) during the maintenance period. The developer will be advised of any corrective maintenance or repair work that is required.

After the maintenance period, Wastewater & Drainage (City of Calgary) is responsible for operation and maintenance. Park Development & Operations typically provides cleanup and maintenance for the areas above the HWL immediately adjacent to the ponds. Prior to acceptance of the stormwater system, the developer is responsible for any maintenance or cleaning required. This includes sediment removal from erosion control ponds, stormwater ponds and BMPs.

A limited number of private maintenance agreements have been set up. In these circumstances, the owner is responsible for the ongoing maintenance required for the facility. Where the owner is negligent in maintaining a minimum standard of care for the system's upkeep, Wastewater & Drainage will bill the owner for maintenance services required. As well, optional amenities may be removed and/or repaired if maintenance is inadequate. When the situation cannot be adequately resolved, Wastewater & Drainage may revoke the maintenance agreement and seize any holdback funds used to set up the agreement.

10.1.4 Inspections

Regularly scheduled inspections and activities are required for the stormwater system to ensure proper operation. The frequency of maintenance will vary with the activity. Unfortunately, the frequency may not be definitely known due to the limited information available. Therefore, many maintenance tasks may be performed on an "as required" basis. Where possible, the frequency will be recommended for the activities described. Otherwise, inspections should be conducted on a monthly basis and after significant rainstorms.

Standard Operating Procedures (SOPs) are being developed to provide additional inspection and maintenance activity information. Other factors, such as land use and upstream development, should be taken into consideration. It should be noted that the SWAMP program (Stormwater Assessment Monitoring and Performance Program) in Ontario is currently endeavouring to monitor and evaluate some of these maintenance activities.

10.1.5 Contacts

During the maintenance period, the developer or the developer's consultant should be contacted regarding inspection, maintenance, and operational issues. If the developer is negligent in carrying out the required work, then Wastewater & Drainage (Systems Maintenance and/or Design groups) should be contacted to resolve the issue(s).

After the maintenance period, all calls should be directed to Wastewater & Drainage (Systems Maintenance Supervisor).

For private maintenance agreements, the owner should be contacted directly. Wastewater & Drainage should be contacted when the owner is negligent in carrying out the required work.

10.1.6 Equipment Access

It is imperative that access for maintenance equipment be included in the design of the stormwater system and ponds. Access to wet ponds and wetlands must be provided for scrapers, tractors and trucks to facilitate sediment removal. Fences, landscaping or other works, should not obstruct these access points. See **Section 6.0 Stormwater Ponds** for more information.

10.2 Operation and Maintenance Activities

10.2.1 Minor System

The minor system and associated components are typically subject to problems such as clogging and collapse. Maintenance is required to preserve the capacity of the system, otherwise potential flooding can occur. Regular maintenance ensures that the stormwater pipe system functions properly.

Wastewater & Drainage maintains a database of all pipes, manholes, catchbasins and service connections. Complaints, inspections and repairs are kept up-to-date and provide a valuable tool.

Preventive maintenance includes:

- Cleaning of streets (serviced by Calgary Roads)
- Sediment removal from catchbasins
- Steaming of frozen catchbasins, outfalls and culverts
- Regular maintenance and cleaning of weirs, skimming manholes, stormceptors and other similar appurtenances
- Repair or replacement of damaged pipe, manholes, catchbasins and other appurtenances

- Inspection of pipe condition by visual or video as required, and
- Review and updating of records for database

Corrective maintenance includes the immediate repair or replacement of pipe breaks and collapses. It also includes looking after hazardous and chemical spills that enter the pipe system; in these situations, it is imperative that efforts are made to prevent the spill from entering and contaminating the river system. **All hazardous spills must be reported immediately to the Fire Department and Alberta Environment.**

10.2.2 Stormwater Ponds

10.2.2.1 General

Regular maintenance activities are required at all stormwater ponds to maintain safety, aesthetic appearances, recreational utility, and operational integrity. Activities relate both to the actual water body (wet ponds and wetlands) and to the adjacent land. These include, but are not limited to maintenance of water quality, maintenance of inlet, outlet and control structures, sediment removal, weed control, etc.

All ponds have a regular maintenance program that includes inspection and maintenance on an ongoing rotational basis starting in the spring. During and immediately after significant rainstorms, all ponds must be checked; repair and maintenance is to be conducted as required. See **Appendix I** for **Pond Standard Operating Procedures**. **In all circumstances, ponds on school sites are to have high priority.**

During a rainstorm event, Wastewater & Drainage is responsible for securing the stormwater ponds as required and general cleanup of the pond afterwards. Park Development & Operations provides cleanup and maintenance of the areas immediately adjacent to the pond. During the maintenance period, the developer will be contacted regarding any further maintenance or repair required as a result of the rainstorm.

Design of stormwater ponds should facilitate maintenance activities. Key areas should focus on access, emergency escape routes, forebays, maintenance/drawdown pipes and bypasses.

10.2.2.2 Control of Hazardous Spills and Chemical Treatment

The main purpose of wet ponds and wetlands is to provide water quality enhancement. Although aquatic vegetation further enhances pollutant removal, hazardous spills can have detrimental effects on vegetation. It is imperative that efforts are made to prevent hazardous and chemical spills from getting into the stormwater pond where it could ultimately discharge to the river system. In many of the ponds, special structures on the inlets have been constructed for containment purposes. **All hazardous spills must be reported immediately to the Fire Department (911) and Alberta Environment (1-800-222-6514).**

Chemical treatment of wet ponds and wetlands to treat special problems (ie. turbidity, algal blooms, etc.) is generally discouraged. Where special treatment procedures are required, Wastewater & Drainage should be contacted for review and approval. The application rate and frequency will be determined based on the specific nature of the treatment procedure.

10.2.2.3 Turf & Landscaping

Turf and landscape maintenance can be a significant and costly activity. It is often a regular activity during spring, summer and early fall. The frequency of turf and landscaping activities should conform to Calgary Parks and Recreation's "Development Guidelines and Standard Specifications-Landscape Construction" (latest edition).

Grass cutting is typically undertaken to enhance the aesthetics or "perceived" aesthetics of a stormwater pond. Where possible, grass cutting should be eliminated or limited around the ponds. Use of indigenous grass mixtures and vegetation is encouraged.

Grass cutting is generally dependent on the surrounding land uses and the adjacent homeowners' expectation of manicured appearances. However, manicured turf around wet stormwater facilities attracts geese and fecal bacteria problems can occur as a result. Therefore, limited mown turf can be beneficial. Dry ponds will typically have more manicured turf. Where grass cutting is required, care should be taken to ensure grass clippings are not discarded into the pond, as this increases organic loading to the pond (and ultimately the river system) and creates potential plugging problems.

Tree pruning is also required to the same extent as any other park area. It is advisable to limit the number of trees in the grassed area around a pond to facilitate operation of mowers for fast and efficient cutting. Trees should either be spaced far apart or planted in beds.

10.2.2.4 Debris Removal and Vandalism

Debris and litter can be significant issues that require frequent visits to empty litter containers, remove floating debris and checks for vandalism. In particular, inlet and outlet structures should be checked for blockages due to debris. Even grass clippings can contribute to blockage of gratings and trash racks. Debris removal and inspection of structures should be carried out in the spring; sufficient monitoring should be implemented throughout the remainder of the summer to ensure proper operation of the facilities. To date this has been accomplished by inspection after any significant rainstorm (see **Appendix I**).

Vandalism can involve signage, landscaping, and structures. Vandalized property should be repaired as soon as possible, particularly if it affects operation of the facility or public safety.

10.2.2.5 Control of Weeds, Aquatic Weeds and Algae

Calgary Parks and Recreation's "Development Guidelines and Standard Specifications-Landscape Construction" and "Integrated Pest Management Plan" should be followed for control of weeds.

Weeds

Weeds around the perimeter of stormwater ponds are described as unwanted vegetation. Weeding should be done by hand to prevent destruction of surrounding vegetation. Refer to Calgary Parks and Recreation's "Development Guidelines and Standard Specifications-Landscape Construction" for more information. Herbicide and pesticide use near wet stormwater facilities is discouraged since this may impact water quality. Contact Park Development & Operations for further information regarding use. Use of fertilizers should also be limited to minimize nutrient loading to the ponds.

Aquatic Weeds

The growth of aquatic weeds in stormwater ponds is affected by water depth, turbidity and the availability of nutrients. When the water depth exceeds 1.2m, emergent vegetation is rarely a problem[11]. However, weed growth around the inside perimeter may still create a problem. Methods of weed control in this zone can include the following:

- Soil sterilization along the perimeter with a chemical to restrict weed growth for two years or more.
- Accept the perimeter weed growth. Many people do not consider emergent vegetation, such as cattails, unsightly.
- Cut and remove the weed growth from either the land or water. This is generally a short-term solution that will likely require annual removal.

---

[11] Alberta Environmental Protection, "Stormwater Management Guidelines for the Province of Alberta", 1999

- Drain the pond, remove weed growth, and re-sterilize the perimeter soil.
- Lower the water surface for a period of time (ie. over the winter) to kill the weed growth, then re-establish the water level.

The selected method for weed control is a matter of choice. However, tolerating the growth is the most economical and protects water quality. Other alternatives should also be investigated and approved by Wastewater & Drainage.

Algae

Algal growth can occur in any stormwater pond that has an adequate supply of nutrients. Prolonged warm weather also encourages growth. Algal blooms are most likely to occur in areas of the pond adjacent to the inlets. Effective treatment is possible with the application of chemicals such as alum or lime. The use of pesticides approved by Alberta Environment and Park Development & Operations may also be used; however this should be used as a last option. Consideration should also be given to the timing of chemical applications as this can impact effectiveness.

Frequency of weed control is based solely on an "as required" basis. Where possible, the use of chemical treatment is discouraged. Mechanical harvesting should be used only as necessary. Alternate methods are subject to review and approval by Wastewater & Drainage.

10.2.2.6 Vegetation and Harvesting

It is important that aquatic vegetation in wet stormwater facilities be monitored to ensure it remains healthy and it performs the functions it was designed to carry out. When these objectives cannot be met, vegetation must be re-established or altered to suit the conditions. Determining plant species suitable to Calgary's climate and the required objectives can be difficult and is subject to "trial and error" (**see Appendix E**). Where the original species has not necessarily survived, but has adapted, this may still be acceptable, as long as the overall objective is being met.

When necessary, mechanical harvesting can be used to harvest aquatic plants. Harvesting should only be considered when there is a significant amount of dead vegetation or when the abundance of vegetation growth negatively impacts flood control volumes. Although water quality is promoted in the design of wet stormwater ponds, it must be balanced with flood control (water quantity) objectives also. Harvesting of vegetation should be done on an "as required" basis with input from Wastewater & Drainage and Park Development & Operations.

10.2.2.7 Mosquito Control

The City of Calgary has a mosquito control program. Efforts for control are typically concentrated on larger water bodies where stagnation is evident and on locations where there are large breeding counts. Areal spraying is confined to these areas to obtain the best benefit.

In general, wet stormwater facilities are not sprayed unless there is a major problem. Generally, alternate methods of mosquito control are advocated (ie. increase circulation, control water level fluctuations, ensure quick drying of pond bottom for dry ponds, etc.). Natural predators such as dragonflies and minnows also help control mosquito populations. Where spraying is still required, approval from Park Development & Operations is required.

10.2.2.8 Odour Control

In Calgary, odour has not been a significant problem at stormwater ponds. Design of the ponds can take into consideration methods of controlling odours. These methods may include ensuring adequate water circulation (no deadbay areas), source controls to minimize organic loadings, or sediment removal on a more frequent basis. Although aeration generally aids in the control of odour, it is considered a cure rather than a preventive measure. Organic loadings can be minimized by the harvesting of dead vegetation in and around the pond, and by locating deciduous trees away from the water body. Odour control is carried out on an "as needed" basis.

10.2.2.9 Aeration and Circulation

In general, aeration and circulation equipment is not supported by Wastewater & Drainage due to its limited value. Although aeration and circulation equipment can make the pond environment less conducive to algae and mosquito production, some researchers have found that algae production can be enhanced when oxygen, rather than sunlight or nutrients, is the limiting factor. It is better to ensure that wet stormwater ponds are designed for adequate circulation by avoiding deadbay areas and by controlling the growth of weeds and algae.

Where developers or owners have entered into a private maintenance agreement, and included aeration or circulation equipment in the pond design, the developers/owners are responsible for maintenance and servicing on a regular basis. It may be necessary to remove the equipment in the fall and re-install it during the spring, so it is not affected by winter conditions.

10.2.2.10 Makeup Water

Makeup water can be used for the following:

- Assist in the control of mosquitoes and algae (if it is introduced in a turbulent manner at the right locations)
- Assist in water quality control through dilution
- Assist in water level control when circumstances dictate the need

The most appropriate source for makeup water is the municipal system. Due to the high costs associated with makeup water, it should only be used for water quality control, and even then, only after careful consideration of alternative measures.

10.2.2.11 Sediment Removal and Disposal

Sediment control is one of the most important activities for stormwater ponds. The accumulation of sediments will eventually reduce the storage volume in a pond and/or water quality. Continued discharge of sediment to a wet facility will ultimately degrade the pond's water quality to a point where water quality is no longer acceptable.

Monitoring of sediment buildup is perhaps one of the best means to prevent deterioration of water quality. It is the most easily observed and since many other contaminants are affected by sediment, control of this parameter will lead to control of these other substances.

The frequency of sediment removal is subjective and may vary with the facility and upstream land use. There are several ways to determine when sediment removal is required, but at this point in time, there is no method that is more reliable than another.

- An approximate removal interval can be estimated through computer modelling based on an average TSS removal efficiency.
- TSS removal can be monitored on a regular basis. When a decline of approximately 5% or more from the original removal efficiency is encountered, sediment removal can be implemented.
- The depth of sediment buildup can be monitored. Depth markers should be in appropriate locations indicative of where sediment buildup will likely occur.

- A bottom survey of the pond and/or forebay can be undertaken on a regular basis to determine the rate of buildup.

Design and operation of the facility will dictate the frequency of sediment removal required. If forebays or ponds are being used as temporary erosion control measures, the frequency of cleaning will be more frequent. Forebays and sediment traps will require more frequent cleaning due to their smaller size. Otherwise, when full development of the catchment has been reached, sediment removal from the entire pond would only be expected between 5 and 15 years. Further monitoring is required to provide more reliable estimates. However, with the advent of water quality control, deterioration of water quality will likely be the governing factor.

There are no set or preferred methods for sediment removal. Although dredging (mechanical excavation) has been the predominant method used, Wastewater & Drainage is interested in alternate methods. Hydraulic (suction) dredging is relatively new technology that has also been used. No matter which method is used, it is important to mitigate sediment re-suspension. This can be accomplished with silt curtains, or by scheduling removal maintenance during the driest month(s) of the year or during winter. Prior to FAC, it is the responsibility of the developer to remove sediment from the pond.

Disposal

Generally sediment removed from stormwater ponds is not contaminated to the point where it would be classified as hazardous waste. However, all sediment removed from these stormwater facilities should be tested to determine the appropriate disposal method. Private laboratories should be used to test sediment samples and recommend disposal methods based on acceptable parameter levels. In the majority of situations, disposal at a sanitary landfill will be the likely option. Depending on the quality of the sediment, the material could be used as fill material.

10.2.2.12 Signage

It is important that warning signs be posted at all entrances and critical access points to the ponds to inform the public of the function of the ponds and the inherent danger (see **Appendix D**). Information signs indicating contact numbers, educational information, etc. can also be incorporated. All signs should be properly maintained for public information and safety. Signs should be inspected throughout the year and repaired as required. Installation of signs should occur prior to the CCC inspection.

10.2.2.13 Structures

General

Pond structures such as inlets, outlets, control structures, and dry pond catchbasins (drain inlets) require regular inspection and maintenance to ensure proper operation and safety of the public. This may include removing gravel, debris, grass clippings, and trash. All gratings must be properly bolted and secured. When necessary the internal pipe system(s), adjacent pipe systems and structures should be flushed and the accumulated sediments removed. Inspection should be conducted every spring and after significant rainstorms. See **Appendix I**.

Outlet Valve Adjustments/Water Level Controls

Some ponds, particularly wetlands, may incorporate stop logs to control water levels and discharges to mimic natural pre-existing conditions. Adjustment of these water levels and outlet discharges must still meet water quality, water quantity and set discharge rate criteria (as set out in the Master Drainage Plan report). Where available, operation manuals can be used as a guideline. Wastewater & Drainage and Park Development & Operations should be contacted for further information.

Gate Valves/Automatic Control Gates/Controllers (PLCs)

Gate valves (or bypass valves), automatic control gates and PLCs (process logic controllers) should be inspected, tested and serviced on a regular basis. Maintenance should follow manufacturer's recommended instructions. Maintenance manuals are required from the developer for the installation and use of automatic control gates and controllers.

Trash Racks and Grates

Trash racks (located in the control structure) and gratings (typically on pond catchbasins, inlets and inlet/outlet structures) should be inspected and cleaned on a regular basis, particularly during the rain season. The frequency of cleaning will be a function of the pond design and its operation. For example, gratings with smaller openings will require more frequent cleanings. If trash racks and gratings are not cleaned on a regular basis, the buildup of debris may plug off the openings. This will result in grates blowing off and in the case of trash racks, prevent the ponds from draining.

All grates must be bolted. Bolting should also be checked on a regular basis to ensure it is properly secured and there is no damage from water pressures trying to blow off grates. Any repair work that is required for gratings and bolting should be repaired immediately.

10.2.2.14 Winter Activities

Ice skating is a typical winter activity. However, it is only allowed at certain dry ponds where Park Development & Operations maintains the skating facility. Wastewater & Drainage does not support winter activities, such as ice skating, on wet ponds and wetlands. This is mainly due to the fact that Wastewater & Drainage is unable to monitor ice surface thickness for safety or to supervise activities.

Tobogganing activities at dry ponds are supported provided the facility has been designed to incorporate toboggan hills. These activities are not supported at wet ponds and wetlands due to the ice thickness and monitoring issues.

10.2.2.15 Winter Operation

There are a small number of ponds that have winter bypasses. At the end of the rain season (October), the bypass should be prepared and activated. Prior to the rain season (April), the bypasses should be closed. These bypasses and special features should be highlighted in the operation and maintenance manual prepared for the pond.

10.2.3 Other Best Management Practices

With the implementation of water quality requirements, there will be increasing use of other Best Management Practices (BMPs). The technologies are generally new to Calgary and must be carefully monitored and maintained. Generally, these technologies are implemented for small urban stormwater runoff areas and require more frequent inspection and cleaning. See **Section 8.0** for descriptions of the BMPs.

Many of these technologies are based on infiltration principles and implementation can increase the recharge potential in a catchment area, decrease overland runoff during storm events, and maintain baseflows in adjacent streams during dry weather periods. Potential groundwater contamination must be a consideration along with the predominant soil type. Calgary has a large amount of clay based soils that may preclude implementation of such technologies.

Regular inspections should be conducted. Wastewater & Drainage has adopted the following inspection table based on information compiled by the Ontario Ministry of Environment.

Table 10.1: Inspection Routines for Stormwater Facilities[12]

Type of Facility	Inspection Routine
Wet Ponds Wetlands	(1) Is the pond level higher than the normal permanent pool elevation more than 24 hours after a storm? This could indicate blockage of the outlet by trash or sediment. Visually inspect the outlet structure for debris or blockage. (2) Is the pond level lower than the normal permanent pool elevation? This could indicate a blockage of the inlet. Visually inspect the inlet structure for debris or blockage. (3) Is the vegetation around the pond dead? Is the pond all open water (ie. no bulrushes or vegetation in the water)? Are there areas around the pond with easy access to open water? This will indicate a need to re-vegetate the pond. (4) Is there an oily sheen on the water near the inlet or outlet? Is the water frothy? Is there an unusual colouring to the water? This will indicate the occurrence of an oil or industrial spill and the need for cleanup. (5) Check the sediment depth in the pond. This will indicate the need for sediment removal. The sediment depth can be checked using a gradated pole with a flat plate attached to the bottom. A marker (pole, buoy) should be placed in the pond to indicate the spots(s) where the measurement should be made. A visual inspection on the pond depth can also b made if the pond is shallow and a gradated marker is located in the pond.
Dry Ponds	(1) Is there standing water in the pond more than 24 hours after a storm? This could indicate blockage of the outlet by trash or sediment. Visually inspect the outlet structure for debris or blockage. (2) Is the pond always dry, or relatively dry within 24 hours of a storm? This could indicate a blockage of the inlet or too large of a water quality/erosion control outlet. Visually inspect the inlet structure for debris or blockage. (3) If applicable, is the vegetation around the pond dead? Are there areas around the pond with easy access to open water? This will indicate a need to re-vegetate the pond. (4) Is there a visible accumulation of sediment in the bottom of the pond or around the high water line of the pond? This will indicate the need for sediment removal.
Infiltration Basins	(1) Is there standing water in the basin generally more than 24 hours after a storm? This will indicate a decrease in the permeability of the underlying soil and, depending on the depth of water in the pond after 24 hours, the need for maintenance-sediment removal and roto-tilling of soils. If there is greater that one third the design depth of water in the pond 48 hours after a storm, the basin needs to be maintained. (2) Is the basin always dry, or relatively dry within 24 hours of a storm? This could indicate a blockage of the inlet. Visually inspect the inlet structure for debris or blockage. (3) Is there a visible accumulation of sediment in the bottom of the pond or around the high water line of the pond? This will indicate the need for sediment removal. (4) Are the top few inches of soil discoloured? This may indicate a need for till the soil.
Infiltration Trenches	(1) Is the trench draining? Inspect the depth of water in the observation well. If the trench has not drained in 24 hours, the inlet and pre-treatment facilities should be cleaned (ie. oil/grit separator, catchbasins, or grassed swales). If the trench has not drained within 48 hours the trench may need to be partially or wholly re-constructed to maintain its performance.

---

[12] Ontario Ministry of Environment, " Stormwater Management Planning and Design Manual-DRAFT FINAL", 1999

Type of Facility	Inspection Routine
	(2) Is the trench always dry, or relatively dry within 24 hours of a storm? This could indicate a blockage of the inlet. Visually inspect the inlet structure for debris or blockage.
Filter Strips	(1) Are there areas of dead or no vegetation downstream of the level spreader? This will indicate the need to re-vegetate the filter strip. (2) Are there indications or rill erosion downstream of the level spreader? This will indicate the need to re-vegetate the filter strip. The rill erosion may be caused by non-uniform spreader height. The spreader should be checked near the erosion areas to determine if it is in need of repair. (3) Is there erosion of the level spreader? The spreader should be re-constructed in areas where the spreader height is non-uniform. (4) Is there standing water upstream of the level spreader? This will indicate that the level spreader is blocked. The level spreader should be checked for trash, debris, or sedimentation. The blockage should be removed and the spreader re-constructed if necessary.
Buffer Strips	(1) Are there areas of dead vegetation along the buffer strip? This will indicate the need to re-vegetate the buffer strip.
Filters	(1) Are there areas of dead vegetation in a grass-surfaced filter or a bioretention area? This will indicate the need to re-vegetate the filter surface. (2) Is there standing water in the filter more than 24 hours after a storm? This will indicate a blockage I the filter, possibly in the perforated pipe collection system or sedimentation on the surface or in the sand layer. The outlet collection system should be inspected for blockage. If there is water in the filter 48 hours after a storm, sediment removal should be undertaken. If sediment removal does not improve the performance (drainage) of the filter, the filter may need to be re-constructed. (3) Is the filter always dry? This could indicate a blockage of the inlet. Visually inspect the inlet structure for debris or blockage. (4) Is there a visible discolouration of the top of the filter or accumulation of sediment on the filter? This will indicate the need for sediment removal and/or replacement of the top few inches of the filter.
Oil/Grit Separators	(1) Is there sediment in the separator/catchbasin? The level of sediment should be measured using a gradated pole with a float plate attached to the bottom. The pole should be gradated such that the true bottom of the separator/catchbasin compared to the cover/grate is marked for comparison. (2) Is there oil in the separator/catchbasin? A visual inspection of the contents should be made from the surface for trash/debris and/or the presence of an oil/industrial spill. An oily sheen, frothing or unusual colouring to the water will indicate the occurrence of an oil or industrial spill. The separator/catchbasin should be cleaned in the event of spill contamination.
Roof Leader Discharge to Soak-Away Pits	(1) Are there frequent overflows to the surface during small storm events? Frequent overflows will indicate that the roof leader filter has clogged or the soakaway storage media has become clogged. The filter should be checked for an accumulation of leaves and twigs. If the filter is clean, the pit may need to be reconstructed to maintain its performance.
Perforated Pipe Systems	(1) Are the pre-treatment stormwater facilities operating properly? Pre-treatment stormwater facilities should be inspected (see oil/grit separators, grassed swales). (2) Is the perforated pipe operating properly? The connection to the perforated pipe (ie. manhole/catchbasin) should be visually inspected for standing water 24 hours after a storm. Standing water will indicate the need for maintenance of the perforated pipe system (flushing, jet washing).
Pervious Catchbasins	(1) Is sediment collecting in the catchbasin? The level of sediment in the sump should be measured using a gradated pole with a flat plate attached to the

Type of Facility	Inspection Routine
	bottom. The pole should be gradated such that the true bottom of the catchbasin compared to the grate is marked for comparison. (2) Is there oil in the catchbasin? A visual inspection of the catchbasin contents should be made from the surface for trash/debris and/or the presence of oil/industrial spills. An oily sheen, frothing or unusual colouring to the water will indicate the occurrence of an oil or industrial spill. The separator/catchbasin should be cleaned in the event of spill contamination. (3) Is the catchbasin infiltration system working properly? The catchbasin should be visually inspected for standing water near the invert of the storm sewer 24 hours after a storm.
Grassed Swales	(1) Is there standing water in an enhanced grass swale. This will indicate a blocked check dam or decrease the permeability of the swale. The check dam should be inspected for blockage by trash/debris, or sediment. (2) Is the grass/vegetation dead? This will indicate the need to re-vegetate the swale. The use of inappropriate grass/vegetation species, exposure to toxins, etc. may cause dead grass/vegetation. (3) Is there erosion downstream of the swale? This may indicate frequent overtopping of the swale, and as such, blockage of the dam or decreased swale permeability. The dam should be inspected for blockage and the erosion corrected by sodding. There may be a need to provide further erosion control (rip rap, plant stakings) to prevent the re-occurrence of erosion).

10.2.3.1 Filtration System (Soakaway Pits)

Soakaway pits are normally used to infiltrate relatively clean water from areas such as rooftops. This reduces the potential for clogging and maintenance. The filter should be cleaned on an annual basis during the fall (after the leaves have fallen off the trees). Frequent overflows during small summer rainstorms indicate that maintenance of the filter is required. See **Section 8.3.3** for design.

10.2.3.2 Infiltration Trenches

Infiltration trenches typically consist of an excavated trench 0.6m to 3m in depth, that is filled with gravel and an underlying sand filter layer. This forms a temporary underground storage reservoir whereby the stored runoff infiltrates into the surrounding soil. Filter cloth may be used to protect the gravel from clogging. Stormwater is conveyed to the trench through an underground pipe system or overland. See **Section 8.3.6** for design.

Maintenance of infiltration trenches involves the removal of sediment from inlet control devices (pre-treatment controls). If sediment controls are not provided, infiltration potential of the trench will be significantly decreased. Maintenance of the trench at this point usually involves re-construction.

10.2.3.3 Pervious Pipe System

Little is known about the maintenance requirements of pervious (or perforated) pipe systems. Monitoring of these systems is required to provide proven maintenance techniques. If a pervious pipe system fails, the only recourse available is usually re-construction of the pipe system. Upstream sediment control is important to decrease plugging potential and increase longevity of the system. If the perforated pipe system does require cleaning, then flushing, radial washing[13] or jet flushing[14] can be tried; however, none of these techniques have been tested extensively for this type of system. See **Section 8.4.1** for design.

10.2.3.4 Pervious Catchbasins

Pervious catchbasins normally discharge to an infiltration trench or to surrounding soils. The pervious catchbasin acts as a sediment trap and must be frequently cleaned out to prevent clogging. Pervious catchbasins serve as pre-treatment controls for other stormwater facilities. See **Section 8.4.2** for design.

10.2.3.5 Grassed Swales

Grassed swales convey stormwater runoff to other stormwater management facilities or receiving streams. The swales are designed to infiltrate the stormwater runoff prior to discharging from the swale. Maintenance includes sediment removal to maintain infiltration effectiveness, and debris removal. The vegetative cover in the swale reduces flow velocity, soil compaction and erosion. Denuded areas should be re-vegetated. See **Section 8.4.3** for design.

10.2.3.6 Infiltration Basins

Infiltration basins are impoundments with relatively high permeable soils. The basins are designed to temporarily store surface runoff and to increase groundwater recharge through infiltration. Sedimentation in these facilities will eventually seal the bottom of the basin, and reduce the infiltration potential. Large amounts of sediments and oils from road surfaces and parking lots may create problems. Therefore, pre-treatment to prevent sediments from entering the basin are helpful. Maintenance of the basin must include sediment removal; this can be accomplished using vacuum trucks to remove accumulated sediments without damaging the bottom of the basin. Other maintenance includes deep tilling of the soil to help maintain its infiltration potential. The planting of deep-rooted legumes may also be beneficial in maintaining soil porosity, and therefore infiltration potential. See **Section 8.5.4** for design.

---

[13] Radial washing is similar in operation to flushing. The perforated pipe must be connected between manholes, and the downstream end plugged or capped. A water hose is connected to the upstream end and the pipe is pressurized, forcing water out of the perforations, thereby cleaning plugged perforations.

[14] In jet flushing, a pressurized hose is attached to a nozzle that discharges in various directions to clean the inside of the pipe. The pressure directs the hose along the length of pipe.

10.2.3.7 Filters

Filters may be constructed as surface or sub-surface end-of-pipe stormwater facilities. Sand is commonly used as the filter media, and may be vegetated with a grass cover. Surface filters that do not have vegetative cover must be raked periodically to reduce surface compaction and clogging. Raking will also remove trash. Additional maintenance should focus on the removal of sediment from pre-treatment controls. See **Section 8.5.5** for design.

10.2.3.8 Filter Strips

Filter strips are vegetated strips which diffuse stormwater runoff directed by a level spreader upstream. The runoff is distributed as sheet flow. Filter strips are similar in many respects to grassed swales. Filter strips slow down surface flow, thereby allowing infiltration and sedimentation. Typically, filter strips are designed for small runoff areas. Maintenance activities involve the maintenance of the vegetated cover and removing sediment upstream of the filter strip. Removal of the upstream sediment can be accomplished using a vacuum truck or conventional small grading equipment such as a bobcat. See **Section 8.6.1** for design.

10.2.3.9 Buffer Strips

Buffer strips are vegetated areas placed adjacent to water bodies. Buffer strips are not generally engineered and do not provide a location for collection of concentrated runoff flows. Sediment removal is not advocated as sedimentation will be dispersed and cleanout would likely destroy the vegetation. However, where vegetation fails to establish itself, re-vegetation will be required. See **Section 8.6.2** for design.

10.2.3.10 Oil/Grit Separators

Oil/grit separators are structures or appurtenances that separate sediment and oil from stormwater runoff. Due to the size of the structure, only a small area of runoff can be treated, otherwise efficiency removal is lost. There are primarily two types of oil/grit separators: 3 chamber separator and bypass separator. The 3 chamber separator consists of multiple chambers. Maintenance requires removal of sediment and oil as required. Bypass separators, such as Stormceptors and Vortechnics, are more easily maintained by vacuum trucks. Entry into the structure is not required. Cleaning should be carried out annually and after any known spills have occurred. See **Section 8.6.3** for design.

10.2.4 Pumping Facilities

Pumping facilities are infrequently used in stormwater management systems. Implementation of pumping facilities is strongly discouraged where gravity drained systems can be implemented. Pumping stations are a major concern in stormwater systems because they are infrequently utilized and the consequences of failure can be severe if not designed properly.

10.2.5 Monitoring Requirements

10.2.5.1 Water Level and Water Quality

Monitoring is important to ensure proper facility design and operation. Wastewater & Drainage requires two types of monitoring: water level monitoring and water quality monitoring.

All stormwater ponds are required to have remote water level monitoring (See **Section 6.1.9**). This allows monitoring by City Systems Maintenance and Design staff when the pond is being used for storage purposes. The water level monitoring equipment activates the alarm system, based on various conditions.

Water quality monitoring is required at all wet ponds and wetlands during the maintenance period. The program must be approved by the Water Quality Engineer in Wastewater & Drainage. See **Sections 7.5** and **7.8**. The purpose of water quality monitoring is to ensure ponds are meeting established water quality parameters. Currently, this is a minimum removal rate of 80% for TSS for particle sizes $\geq 75\mu m$.

10.2.5.2 Annual Maintenance and Checks

It is important that the water level monitoring equipment be checked on an annual basis prior to the start of the rain season (spring) and on an "as needed" basis during the rain season. See **Appendix I**. All equipment and alarm settings must work properly. Wastewater & Drainage conducts all monitoring checks. The developer is responsible for the cost of any repairs required during the maintenance period.

10.2.6 Operating and Maintenance Manual

An operating and maintenance manual must be prepared by the owner/developer, or his designated consultant, for **all** stormwater ponds (see **Section 6.1.8**) and other BMP technologies (as required). The manual is required to ensure all facilities are operated and maintained properly, particularly when there may be special features incorporated (ie. automatic control gates, water level control logs, vegetation requirements, etc.). The manual should be submitted as part of the CCC. Information in the manual should include, but is not limited to the following:

- Schematic or plan of facility showing pertinent structures
- Detailed schematics of components as required
- List of additional mechanical and electrical equipment used in the design of the facility. This shall include equipment/part lists, manufacturer's operation requirements, maintenance, service and repair instructions, and warranties
- Proposed operating instructions for normal and emergency conditions
- Itemized maintenance list and proposed checking and cleaning schedules
- Long term and short term maintenance requirements for vegetation

Wastewater & Drainage will forward a copy of the manual to the Systems Maintenance group who is responsible for maintenance.

10.2.7 Capital and Operating Costs

Capital and operating costs of stormwater facilities (BMPs) can be difficult to estimate for construction and maintenance activities. However, the cost of stormwater systems is important to overall development and should not be overlooked when assessing alternative stormwater management systems. Maintenance and operation costs are, arguably, the most important since these facilities and systems must be maintained and operated in perpetuity.

Most BMPs are very site specific and design may vary due to local conditions, design objectives, land uses and public preferences. Therefore, there may be a great deal of variability in capital and operating costs.

Although Wastewater & Drainage has limited information regarding construction and maintenance of stormwater BMPs, the experience of other municipalities can be useful to designers in their efforts of selecting appropriate BMPs. It is necessary for designers to examine the costs on a site-by-site basis for each BMP selected. Wastewater & Drainage is trying to track construction and maintenance costs, but most of the information is for stormwater pond BMPs.

Cost Components

The total cost of implementing stormwater BMPs includes a number of components which relate to administration, planning and design, land acquisition, site preparation and development, and operation and maintenance.

Capital Costs: This represents the total cost, including labour and materials, associated with the actual construction of the BMP facility

Engineering Costs: This includes the planning, design and construction management costs of the BMP facility. Engineering costs are often estimated at 10% of the total capital cost.

Contingency Costs: This includes unforeseen costs that occur over the construction period. Contingency costs are often estimated at 15% of total capital cost.

Operation and Maintenance Costs: This represents the costs required to ensure the proper operation, longevity, and aesthetic functioning of the BMP at acceptable levels. This should also include any source control costs required.

11.0 Technical Requirements

This section details the requirements for stormwater reports and engineering (construction) drawings. Additional information may be requested from time to time by Wastewater & Drainage for complex sites. It should also be noted that the requested information is subject to change.

11.1 Reports

Stormwater reports are typically required to establish technical backup demonstrating the viability of proposals and ultimately the basis for detailed design. Specific storm sewer and drainage concerns must be addressed at an appropriate and increasing level of detail as planning and development proceeds. The reports provide continuity to the progressing development areas. Table 1.1 in **Section 1.0** illustrates the planning process and when the different types of reports are required. Listed in the following sections are the report requirements for the different types of plans. Definitions can be found in **Section 1.0 Stormwater Management and Planning**.

11.1.1 River Basin Plan (RBP)

River Basin Plans are typically a provincial responsibility. At this level, issues will concern the supply and demand for water as a resource. Water quality is a significant factor at this level. Report requirements are established by the province when the work is to be commissioned by a qualified consultant or group of consultants.

11.1.2 Watershed Plan (WP)

Watershed Plans are generally carried out as a joint responsibility between the City of Calgary and the province. WPs provide a conceptual framework for stormwater and drainage servicing. At this level, structural components may include servicing options, drainage and environmental constraints, BMPs, stormwater ponds and alternatives. Non-structural components may include economic issues, staging, utility corridors, biophysical impact assessments, and performance criteria. Report requirements are established by Wastewater & Drainage and the province at the time the Watershed Plan is commissioned. Reports are to be undertaken by qualified consultants.

11.1.3 Master Drainage Plan (MDP)

A Master Drainage Plan report generally covers a portion of the area served by a watershed plan. Although the MDP is often for an area serviced by one outfall, it can include more than one outfall.

11.1.3.1 Submission & Technical Requirements

a) The MDP should be developed through the evaluation of alternatives that provide an acceptable level of service while meeting the objectives of the watershed plan and satisfying constraints imposed by topography, land uses, and land ownership. The MDP should identify and locate major stormwater ponds, other BMPs, approximate trunk sizes and servicing routes, overland drainage routes, water quality requirements, and land requirements. Servicing options should also be investigated where required with recommendations for the most practical alternative. Information can be obtained from Wastewater & Drainage for catchment area boundaries and permitted release rates. The technical requirements for an MDP report are similar to those required for a Staged Master Drainage Plan (SMDP) report (see **Section 1.1.2**). If SMDP reports are anticipated at a later stage, the MDP report can be more general in nature.

b) Submission of an MDP report is required prior to approval of Outline Plans (OP) or Staged Master Drainage Plans (SMDP). Biophysical Impact Assessments should be conducted prior to or in conjunction with the MDP report. Any additional issues will be established by the Systems Planning group in Wastewater & Drainage.

c) Alberta Environment should be involved in the development of the MDP at the early stages. Alberta Environment will review the MDP report and submit comments if necessary. Sufficient review time must be allowed for provincial and municipal review.

d) **All reports must be prepared by qualified consultants.** Reports must include the Professional Engineer and company permit stamps.

e) A total of **six (6)** copies of the report are required for review purposes. All reports must be forwarded to the Storm Systems Engineer in Wastewater & Drainage. Copies of the report will be then be forwarded to the appropriate reviewing personnel or agencies, including Alberta Environment.

11.1.4 Staged MDP (SMDP)

A Staged Master Drainage Plan (SMDP) typically includes a large area that may or may not be serviced by an outfall. The SMDP generally covers a portion of the areas served by an MDP. An SMDP is not necessarily required in all circumstances. An MDP may be sufficient provided there is enough detail, the catchment boundaries have not significantly changed, or there is no significant deviation from the stormwater management system proposed. The drainage area for an SMDP should not be based on jurisdictional boundaries, as this may not provide the best servicing concept for the area.

Similar to an MDP, the SMDP should identify and locate major stormwater ponds, other BMPs, trunk sizes and servicing routes, overland drainage routes, water quality requirements, and land requirements. Preliminary design of the major ponds and BMPs should be included in the report, otherwise a separate report for the ponds will be required.

11.1.4.1 Submission Requirements

a) Submission of an SMDP report is required prior to approval of the Outline Plan if no Master Drainage Plan Report exists. Otherwise, submission of the SMDP is required prior to approval of construction drawings. Biophysical Impact Assessments should be conducted prior to or in conjunction with the SMDP as required.

b) Alberta Environment should be involved in the development of the SMDP at the early stages. Alberta Environment will review the SMDP report and submit comments if necessary. Sufficient review time must be allowed for provincial review.

c) A minimum time period of **three weeks** is required for review and comments by Wastewater & Drainage.

d) **All reports must be prepared by qualified consultants.** Reports must include the Professional Engineer and company permit stamps.

e) A total of **six (6)** copies of the report are required for review purposes. All reports must be forwarded to the Storm Systems Engineer in Wastewater & Drainage. Copies of the report will be then be forwarded to the appropriate reviewing personnel or agencies, including Alberta Environment.

11.1.4.2 Technical Requirements

All SMDP reports should include the following:

a) **Cover Letter:** The cover letter should highlight any unresolved issues or areas where guidelines cannot be met.

b) **Site:** Include overall site description and figure showing location, section number, total area, drainage boundaries, and location area drains to.

c) References and comparison to any existing Watershed Plans or MDPs. Permitted storm release rates (L/s/ha). As required, reference MDPs for adjacent areas.

d) **Methodology**: Brief description of computer model, methodology, design storm parameters, and model schematic. Refer to **Sections 3.0 and 6.0** for requirements.

Storm needs to match peak intensity and depth for the given duration and return period.

e) **Results and Summary:** Preliminary delineation of overland flows and flow routes. Overland flows leaving an area should be zero or be able to be accommodated downstream (consult with Wastewater & Drainage). There should be no adverse impacts to downstream or adjacent areas. Preliminary storage requirements per hectare should be included.

f) Summary of unit area release rates, minor flow rates, preliminary pipe sizes, and proposed pipe elevations at boundaries. A summary of the proposed ponds should include pond types, approximate NWL/HWL elevations, and required 100 year and water quality volumes. No construction drawings are required, but servicing must be shown to be workable. A figure showing the pond locations and storm servicing trunks must be included. Ponds should be adequately sized overall to include forebay areas, topography and any other site constraints.

g) Hydrologic changes to the receiving water body must be addressed (determine pre-development and post-development hydrology).

h) Input and Output computer modelling files.

i) Biophysical Impact Assessment. This will typically be forwarded as a separate report (see **Section 11.1.9** for more information).

If the SMDP report is to include detailed information regarding stormwater ponds, the following additional information is required (see also **Section 11.1.6.1**):

j) Type of pond(s), release rates, proposed storage volumes, size of contributing area to each pond, pond size and location. Affected downstream ponds should also be indicated along with the ultimate outfall.

k) Computer simulations for both 100 year **quantity and quality** (see **Sections 3.0, 6.0 and 7.0** for requirements). A statistical analysis is required for the continuous model to determine the required 100 year storage volume. Water quality analysis for TSS removal is also required.

l) Frequency of inundation analysis. A table showing a minimum of 80% removal of TSS for particle sizes ≥75µm for water quality.

m) Table(s) showing stage, area, volume, bottom/NWL/HWL elevations, and discharge for all of the proposed ponds. Preliminary information for forebay sizing and volume.

n) Input and Output computer modelling files.

o) Preliminary layout of the ponds showing inlet locations, pond structures, pipe locations, and forebays. All pond design must conform to the design standards indicated in **Section 6.0**.

11.1.5 Subdivision (SWMR)

Detailed stormwater management reports must be prepared for areas covering subdivision and outline plans. A report is required for **all** subdivision development phases, and will generally correspond to an applicable set of construction drawings. At this level, details pertaining to the storm sewer and related structures, hydraulic grade line analysis, 100 year storage requirements, trap lows, escape routes, BMPs, and water quality requirements should be included.

11.1.5.1 Submission Requirements

a) Submission of an SWMR report is required **prior** to review and approval of the Final Construction Drawings. Wastewater & Drainage will return, without review, all final construction drawings for which a stormwater report has not been submitted and reviewed.

b) A minimum time period of **three** weeks is required for review and comments by Wastewater & Drainage.

c) **All reports must be prepared by qualified consultants.** Reports must include the Professional Engineer and company permit stamps.

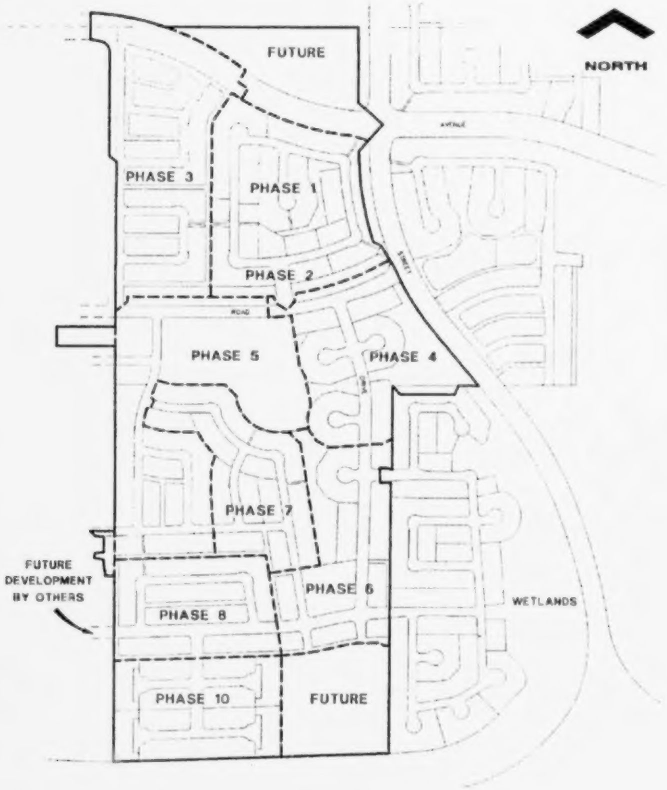
d) **Two (2)** copies of the report are required for review purposes. All reports must be forwarded to the Storm Systems Engineer in Wastewater & Drainage. Copies of the report will be then be forwarded to the appropriate internal reviewing personnel.

11.1.5.2 Technical Requirements

All SWMR reports should include the following:

a) **Cover Letter:** The cover letter should highlight any unresolved issues or areas where guidelines cannot be met (in particular Alberta Environment velocity-depth guidelines).

b) **Study Area & Location:** Include overall site description and figure showing location and section number. It is best to include two figures; one showing the location of the area with respect to the city and the other showing the phase and surrounding phases.


FUTURE
NORTH
AVENUE
PHASE 3
PHASE 1
STREET
PHASE 2
ROAD
PHASE 5
PHASE 4
DRIVE
PHASE 7
FUTURE DEVELOPMENT BY OTHERS
PHASE 6
WETLANDS
PHASE 8
PHASE 10
FUTURE

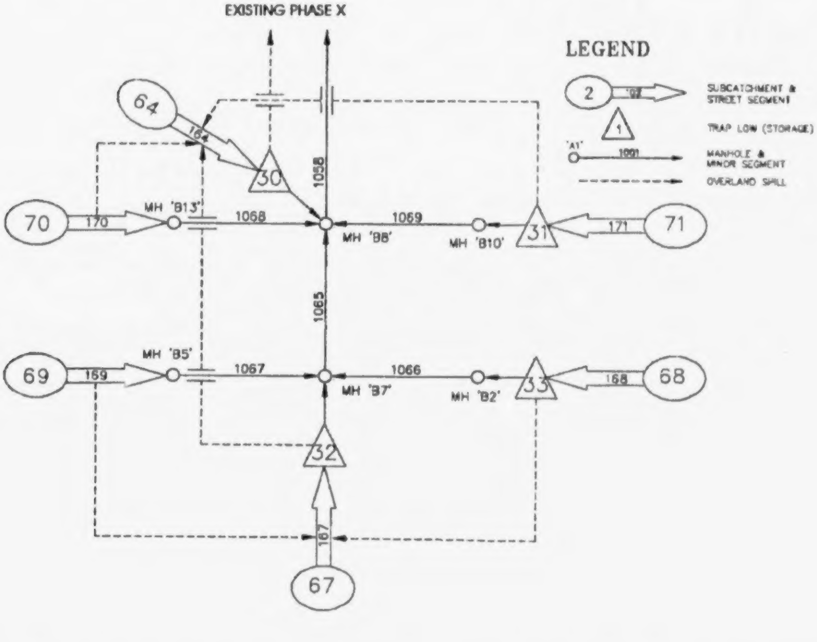
Include reference to applicable MDP/SMDP, permitted release rates (L/s/ha), and any minor and major design objectives. The direction of minor and major drainage should be shown along with any overland flows that enter the subdivision phase.

c) **Subcatchments:** Include a figure delineating subcatchments and sizes of the subcatchments in the subdivision phase. ICDs and special CB interconnections should be included in the figure. Other details such as imperviousness can be included or may be indicated in the computer model.

Subcatchment Data

No.	Description	Area (ha.)	% Impervious	Slope (%)	Width (m)
64	Phase 10 Residential	1.75	50	3.0	400
67	Phase 10 Residential	1.36	65	3.0	320
68	Phase 10 Residential	0.62	71	3.0	160
69	Phase 10 Residential	0.36	55	3.0	90
70	Phase 10 Residential	0.34	55	3.0	90
71	Phase 10 Residential	0.56	78	3.0	160

d) **Methodology:** Brief description of computer model, methodology, design storm parameters (design storm and duration), model input parameters, and model schematic. Refer **to Sections 3.0 and 6.0** for requirements.


EXISTING PHASE X
LEGEND
2
SUBCATCHMENT & STREET SEGMENT
1
TRAP LOW (STORAGE)
'A1'
1001
MANHOLE & MINOR SEGMENT
OVERLAND SPILL
64
164
30
1058
70
170
MH 'B13'
1068
MH 'B8'
1069
MH 'B10'
31
171
71
1065
69
169
MH 'B5'
1067
MH 'B7'
1066
MH 'B2'
33
168
68
32
167
67

Design storm needs to match peak intensity and depth for the given duration and return period.

Results and Summary should include the following:

e) **Summary of Minor Flows:** Include summary of minor flows for the 100 year event to ensure pipe design flows are not exceeded. The summary should include capacity, design flow, and cumulative ICD flows.

ICD TYPES AND LOCATIONS

Area #'s (Manhole) From Dwg. G-1	*ICD Type(s)*	*Allowable Discharge (1) (l/s)*	*Cumulative Discharge (1) (l/s)*	*1:100 Year ICD Flows (2) (l/s)*	*1:100 Year ICD Cumulative Flows*	*Pipe Capacity (l/s)*
# 1,2 (MH '16-A')	R50, R100	123.4	123.4	145.0	145.0	262.1
# 3 (MH '16-B')	R50	43.9	167.3	31.7	176.7	382.1
(ex. MH '13-J')	R30	10.7	727.4 (3)	18.3	721.8 (3)	1194
(ex. MH '13-K')	2-R50's	29.6	757.0 (3)	76.2	798.0 (3)	1194
#4,5 (fut '16-D')	R50, R70	110.2	110.2	85.4	85.4	160.5
#6,7 (fut. '16-E')	R70, R70	108.6	218.8	124.2	209.6	301.4
(ex. MH '13-M')	n/a	-	975.8 (3)	-	1007.6 (3)	2104

(1) Allowable discharge based on 51 l/s/ha.

(2) 1:100 year flows based on capacity of ICDs.

(3) Discharges include areas from Phase X report

Minor System Flows

Minor Segment No.	Rated Capacity (m^3/s)	Design Flow (m^3/s)	1:100 Peak Flow (m^3/s)
1058	0.497	0.303	0.255
1065	0.211	0.150	0.118
1066	0.072	0.043	0.039
1067	0.148	0.025	0.019
1068	0.190	0.023	0.019
1069	0.072	0.039	0.038

Minor flows must be sized for upstream areas if applicable and flow conditions at tie-in points must not exceed design flows. The minor system must be adequately designed in terms of hydraulics (see **Section 5.0 Hydraulic Design**).

f) **Surcharge (HGL) Analysis:** An HGL analysis is required on a site specific basis for areas impacted by the HWL from stormwater ponds or other conditions (see **Section 5.0 Hydraulic Design**). Surcharge to surface will NOT be accepted. The HGL must be based on the pond at HWL and the appropriate losses taken into account. A table indicating HGLs must be included with the analysis.

g) **Trap Low Storage:** A table showing all of the trap lows in the phase and those on the boundary must be included. The table must include required 100 year volumes, depths and elevations, and design (also called maximum or spill) volumes, depths and elevations. Minimum Building Opening Elevations (MGs) and restrictive covenants (RMGs) should be included.

TRAP LOW DESCRIPTIONS

Trap Low	1:100 Year Volume (m^3)	1:100 Year Depth (m)	1:100 Year Elev. (m)	Spill Volume (m^3)	Spill Depth (m)	Spill Elevation (m)
1 [(4)]	580	0.494	1218.019	368	0.412	1217.937
2	276	0.427	1217.792	422	0.492	1217.857
3	220	0.418	1221.466	191	0.395	1221.443
future [(5)]	n/a	n/a	n/a	231	0.497	1215.391

[(4)] Information from Phase x storm report.

[(5)] Future trapped low is included for information only. Analysis with future phase.

Storage Volumes, Depths and Elevations

Storage No.	Spill Condition			1:100 Year Event Results				MG[1] Elevation (m)
	Storage (m^3)	Depth (m)	Elevation (m)	Volume Stored (m^3)	Volume of Spill (m^3)	Depth (m)	Elevation (m)	
30	271	0.30	1098.85	248	0	0.29	1098.84	1099.15
31	202	0.29	1098.85[2]	77	0	0.18	1098.73	1099.15
32	294	0.30	1098.90	256	0	0.28	1098.88	1099.20
33	120	0.22	1098.90[3]	88	0	0.28	1098.88	1099.20

1. Minimum building grade or house entrance.
2. Elevations are governed by Storage#30.
3. Elevations are governed by Storage#32.

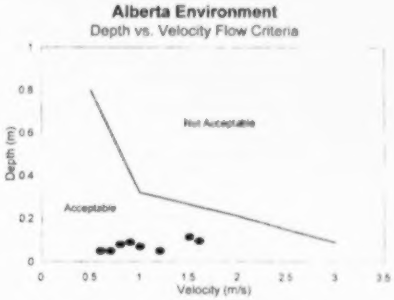
h) **Overland Flows:** Show overland flows (Q, v and d) entering the subdivision from adjacent land. Flows should be zero, unless accounted for previously. Some areas must be designed for total containment within the phase. Where overland flow leaves the subdivision, Wastewater & Drainage may request that the impact on downstream areas be assessed.

Q, v and d must be shown for key overland flow routes, including critical gutter segments. Flows entering and leaving phase boundaries must also be shown. These flows should be summarized.

1:100 Year Event Overland Flows

Segment No.	Peak Flow (m^3/s)	Depth (m)	Velocity (m/s)
124 (Spill)	0.608	0.11	1.85
124A	0.675	0.11	1.88
125A	0.230	0.07	1.45
128 (Spill)	0.000	0.00	0.00

Flows should not exceed Alberta Environment depth-velocity guidelines. Graphing the proposed flows against permissible values will quickly indicate any potential problems. Values outside of these limits must be approved by Wastewater & Drainage.



i) Input and Output computer modelling files.

j) **Overland Drainage Drawing:** An overland drawing must be included in all SWMR reports. See **Section 11.2.1.2** for drawing requirements.

11.1.6 Stormwater Ponds

Reports must be submitted for all dry ponds, wet ponds and wetlands. Evaporation ponds may also require report submission (see **Section 11.1.7** for more information); contact Wastewater & Drainage for more information. A pond report may be either a stand-alone report or be included in the MDP/SMDP report. If details of the pond are likely to change significantly, a separate report is recommended; then the MDP/SMDP can provide more generalized information on the ponds.

11.1.6.1 Submission Requirements

a) Submission of a pond report is required **prior** to review and approval of the Final Construction Drawings. Wastewater & Drainage will return, without review, all final construction drawings for which a pond report has not been submitted and reviewed. **Stormwater ponds must be in place, or approved for construction, prior to the first phase(s) of development being approved for construction.**

b) Alberta Environment should be involved in the development of the pond report at the early stages. Alberta Environment will review the Stormwater Pond report and submit comments if necessary. Sufficient review time must be allowed for provincial review. Approval to construct the pond must also be given by Alberta Environment. **All ponds must be advertised and undergo a 30 day Public Notification period (see Section 2.0 Approvals & Processes). It is imperative that all approvals be in place prior to construction.**

c) A minimum time period of **three** weeks is required for review and comments by Wastewater & Drainage.

d) **All reports must be prepared by qualified consultants.** Reports must include the Professional Engineer and company permit stamps.

e) A total of **three (3)** copies of the report are required for review purposes. All reports must be forwarded to the Storm Systems Engineer in Wastewater & Drainage. Copies of the report will be then be forwarded to the appropriate internal reviewing personnel and Alberta Environment.

11.1.6.2 Technical Requirements

All pond reports should include the following:

a) **Cover Letter:** The cover letter should highlight any unresolved issues or areas where guidelines cannot be met.

b) **Site:** Include overall site description and figure showing location of pond, section number, total area, and drainage boundaries. Affected downstream ponds should also be indicated along with the ultimate outfall location.

Include reference to applicable MDP/SMDP and permitted discharge rates.

c) **Subcatchments:** Include a figure delineating subcatchments or drainage area for the stormwater pond.

d) **Methodology:** Brief description of computer model, methodology, design storm parameters (design storm and duration), model input parameters, and model schematic. Refer **to Sections 3.0 and 6.0** for requirements.

e) Computer simulations for both 100 year **quantity and quality** (see **Sections 3.0, 6.0 and 7.0** for requirements). A statistical analysis is required for the continuous model to determine the required 100 year storage volume. Water quality analysis for TSS removal is also required.

Results and Summary should include the following:

f) Type of pond, release rate, required storage volume (quantity and quality), proposed pond size, pond elevations (bottom, NWL, HWL), pond sizing requirements (length, width,), and forebay sizing and volume.

g) Frequency of inundation analysis. A table showing a minimum of 80% removal of TSS for particle sizes ≥75μm for water quality.

h) Table(s) showing stage, area, volume, bottom/NWL/HWL elevations, and discharge for all of the proposed ponds.

i) Preliminary drawings showing pond outline, pond elevations (bottom, NWL, HWL), sediment forebays, control structures, inlet/outlet structures and discharge control. All pond design must conform to the design standards indicated in **Section 6.0**.

j) Escape Route from pond and details.

k) Preliminary Surcharge (HGL) Analysis: Surcharge adjacent to pond area to be kept to a minimum. Detailed HGL analysis can be submitted with the subdivision stormwater report (SWMR).

l) Input and Output computer modelling files

m) Weeping Tile/Subdrainage System design for dry ponds

n) Geotechnical: Determine requirement for pond lining, toe drains, french drains, etc. as required.

11.1.7 Drainage & Site Servicing Plans (DSSP)

Generally, detailed stormwater management reports are **not** required for the majority of DSSPs. The following situations require computer modelling and reports: serviced sites larger than 2 ha, sites requiring stormwater ponds, and non-serviced sites larger than 2 ha.

11.1.7.1 Submission and Technical Requirements

a) **Serviced sites ≤ 2 ha do not require detailed stormwater management reports for determining required storage volumes.** Storage volumes may be determined through manual calculations and graphs. See **Section 4.7.1**.

b) **Non-serviced sites ≤ 2 ha do not require detailed evaporation pond reports for determining required storage volumes.** Storage volumes for evaporation ponds may be determined through the graph in **Section 4.8.6**.

c) **Serviced sites > 2 ha require detailed stormwater management reports for determining required storage volumes.** Submission and technical requirements for Subdivision Reports (SWMR) should be followed. See **Section 11.1.5**.

d) **Non-serviced sites > 2 ha require detailed evaporation pond reports for determining required storage volumes.** Submission and technical requirements for Pond Reports should be followed. See **Section 11.1.6**. The computer modelling should adhere to the requirements stipulated in **Section 4.8.6**. Since there is to be no discharge from an evaporation pond, water quality modelling can be eliminated.

11.1.8 Special Projects and Contracts (SP)

All special projects and contracts (SP) are required to conform to stormwater management designs and policies, whether they are designed within the City by other business units or through external consultants.

11.1.8.1 Submissions and Technical Requirements

Submission and technical requirements for special projects and contracts should conform to the requirements for subdivisions (SWMR), stormwater ponds, and/or drainage & site servicing plans (DSSP) reports as required. For further information, contact Wastewater & Drainage.

11.1.9 Biophysical Impact Assessment

The purpose of the BIA is to examine the potential impacts of future development on biophysical elements (ecosystems, landforms and habitats) and to successfully integrate stormwater management (utilities and facilities) within the planning area.

The BIA is to be done in collaboration with Park Development & Operations and Wastewater & Drainage to meet mutual objectives. The consultant is to contact Park Development & Operations for BIA scope, requirements and issues to be addressed. A BIA may be quite simple or complex depending on the area (community) and/or size. Environmental strategies may be provided in the Natural Area Management Plan (NAMP) prepared by Park Development & Operations. Natural habitat types may be identified on a small scale in the NAMP; however, further inventory may be required.

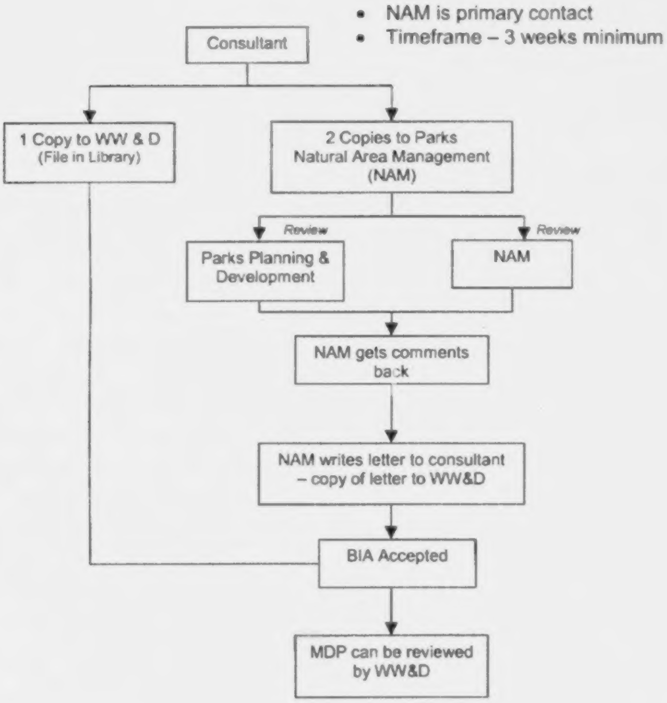
11.1.9.1 Submission Requirements

a) Submission of a Biophysical Impact Assessment (BIA) is required **prior** to or in conjunction with the Master Drainage Plan Report. Where a BIA has not been previously completed, one will be required with the Staged Master Drainage Plan Report.

b) The BIA report will typically be a stand-alone report. However, when warranted, it can be included in the MDP or SMDP report. The consultant must submit **two** (2) copies of the BIA report to Parks Natural Area Management and **one** (1) copy to Wastewater & Drainage. A period of **three** weeks minimum is required for review and comments by Parks Natural Area Management.

c) Alberta Environment, Water Sciences Branch, must review BIAs where ponds are adjacent to watercourses as a requirement of the provincial stormwater pond approval process. Wastewater & Drainage will forward a copy of the BIA along with the application to Alberta Environment; the consultant must provide an extra copy of the BIA in these circumstances.

Figure 11.1: Review Process for BIAs



NAM is primary contact
Timeframe – 3 weeks minimum
Consultant
1 Copy to WW & D (File in Library)
2 Copies to Parks Natural Area Management (NAM)
Review
Review
Parks Planning & Development
NAM
NAM gets comments back
NAM writes letter to consultant – copy of letter to WW&D
BIA Accepted
MDP can be reviewed by WW&D

d) All BIAs must be prepared by competent consultants.

11.1.9.2 Technical Requirements

The Biophysical Impact Assessment Report should dovetail with Appendix F and G of "Calgary Open Space Plan" by Calgary Parks and Recreation (2000). A competent consultant with expertise in this area is required for the report or as a subconsultant for the report.

The BIA should be a collaborative effort between Park Development & Operations and the consultant to determine the scope and extent of the study. If sufficient information exists, the BIA will be relatively simple. Where more investigation is required, the evaluation should be conducted over a minimum of one growing season (May to October). BIAs should be done as far in advance as possible to avoid unnecessary delays. BIAs are subject to approval by Park Development & Operations.

All Biophysical Impact Assessment Reports should include the following:

1. Description

Overall Site Description	overall description of study area, location, section number (and/or legal description where required), maps, total area reference to any existing Watershed Plans or MDP's, reference to MDP's for adjacent areas
Purpose	detailed background information for the proposed activity (ie. stormwater pond, outfall, storm and sanitary sewer alignment)
Existing Impacts and Policies	identify current land use, any existing Natural Area Management Plans, and any existing internal or external policies that may direct or influence the proposal, etc.
Objectives	identify biophysical management objectives
Miscellaneous	where applicable identify capital cost and financing constraints, use of natural resources or disruption during construction, etc.

2. Inventory of Biophysical Environment

Topography Physiography	physical description of existing land forms, slopes, aspects and position within the landscape
Geology Hydrogeology Geomorphology Soils	description of surficial and subsurface geological features and soils; emphasis should be on the impacted site(s) and immediate environment, identify glacial land forms and stability issues
Vegetation	identify on-site flora with emphasis on habitat value, wildlife corridor importance, and the role of resident vegetation within the localized system. Include a rare species summary where necessary
Wildlife	identify on-site fauna with emphasis on habitat value, wildlife corridor importance, and the role of wildlife within the localized system. Include a rare species summary where necessary
Hydrology Fisheries	identify all streams, rivers, lakes, wetlands, other wet bodies, springs or other natural hydrological sources. Also identify surficial drainage patterns, water table, water quality, fish habitat, and other features

Aesthetics	subjective description of how the site fits into the landscape and/or cityscape, and other significant features such as approved City policy and plans. This may include prominent views, human disturbance, aesthetic features, hydrological/biological/geological resources, etc.
Cultural Resources (Prehistoric, Historic and Current)	identify existing historical, interpretive, or recreational features and the potential for developing recreational, interpretive, or educational facilities at the site
Other Features	descriptions or other features which may be of importance or interest to the site but are not included in the above categories (ie. power lines, buildings, roads)

3. Impacts

Biological Resource Impacts	comprehensive account of actual and potential risks/benefits from development activity to wildlife habitat, overall biodiversity, sensitive plant and animal populations, movement corridors, rare or threatened plants and animals, long-term flora, and fauna community stability
Geographical and Geological Impacts	physical impact of the development activity including: elimination/alteration of unique land forms, alteration of drainage patterns, micro-climate effects, erosion processes, paleontological (surface and subsurface) alterations, slope stability
Visual Impacts	actual and potential impacts of the project from the perspective of the expert and non-expert. Include enhancement/reduction of aesthetic features, alteration/obstruction of view lines, introduction of weeds and/or pests, landscape alteration, etc.
Cultural Impacts	actual and potential impacts of project from a heritage perspective, loss/gain of interpretive resources, impact on historical or archaeological sites, etc.
Social/Economic Impacts	actual and potential costs, loss/gain of recreational resources, localized community impacts, long-term cost (in dollars), capital, manpower, problems created/solved in perception of community
Cumulative Impacts	summary of combined impacts and how this affects rehabilitation, protection and operation of the site in the future
Residual (Unmitigable) Impacts	summary of actual and potential impacts to the site which are inevitable, yet permanent. This may include long-term species diversity, loss of habitat, loss of system connectivity, loss of public access, obstruction of wildlife movement, introduction of weeds or pests, long-term maintenance requirements, removal of natural features, aesthetic impacts, etc.

4. Recommendations

Proposed Stormwater Utilities and Facilities	Identify sites where stormwater utilities and facilities are proposed. Discuss integration with the Biophysical Inventory and impacts. Identify advantages, disadvantages, alternatives, financial constraints, etc.
Mitigation	Identify accepted methods available to mitigate damage and encourage recovery. This may include signage and fencing, grading and loaming, stockpiling, seeding with native mixtures, native plantings, limited-impact construction, etc. Identify experimental methods available to mitigate damage and encourage recovery. This may include sod transplants, loam shredding and re-application, specialized seed/plant harvesting and application, use of organic fertilizers and erosion control methods, etc.

Significance of Impacts	**Regional**-cumulative assessment of impacts to the regional area based on biophysical parameters previously identified. Provide loss/gain of regional resources and long-term effects **City-Wide**-cumulative assessment of impacts to Calgary's urban natural area system. Include details of habitat loss/improvement, effects on system continuity and contiguous natural areas, effects of wildlife movement, large-scale aesthetic impact, and social, cultural, and economic impacts to Calgarians. **Park-Wide**-cumulative assessment of impacts to individual parks but with a focus on identified environmentally significant areas, unique habitats, and representation within the park. Impacts on habitats, system connectivity and system viability. **Local**- small scale approach to impact assessment to include impacts on adjacent vegetation communities, loss/gain of community recreational or natural resources, community economic/social impacts, long-term maintenance requirements, aesthetic impacts, introduction of weeds/pests to community, isolation/connection to city-wide system, etc.

11.1.10 Report Re-Submissions

Once a report has been reviewed, a letter will be sent outlining issues to be resolved for report acceptance. This letter will indicate whether re-submission is required in the form of a letter or a new revised report. Generally, a letter is required when few revisions are required and computer modelling does not need to be re-submitted.

i. If a letter is sufficient to address outstanding issues, a review period of **one week** is generally required.

ii. If a new revised report is required to address outstanding issues, a minimum review period of **three weeks** is required.

11.2 Engineering Drawings

Engineering (construction) drawings are required for approval by Wastewater & Drainage prior to construction permission. Where required, reports must be submitted prior to the engineering drawings. The drawings should reflect the stormwater management concepts and details approved in the reports. The following sections outline the stormwater criteria required for the drawings.

11.2.1 Subdivision

11.2.1.1 Preliminary, Final, and Revised Finals

Currently, there are two drawing submissions required for subdivisions: preliminary and final construction drawings. Revised finals are required when there are significant changes or corrections. Revisions to specific drawings may also be requested. **All circulations must be submitted to Urban Development for internal circulation to the various approving business units.**

11.2.1.2 Drawing Requirements

A set of construction drawings will typically include several drawings. The drawings should include stormwater management information and details as described:

Preliminary

i. **Storm:** The storm system must be designed with hydraulic considerations as required. Preliminary trunk sizing and elevations must be submitted to Wastewater & Drainage prior to circulation.

ii. **Storm Drainage:** The storm drainage drawing must show overall boundaries and release rates. The release rates must agree with the approved MDP or SMDP.

iii. **Erosion & Sediment Control:**
   - Erosion control features for subdivision phase and overall drainage area (as required).
   - Details for erosion control features

iv. Underground and Surface permission for storm is not generally granted for preliminary drawing submission since not all of the stormwater management and design information is normally included at this stage.

Finals

i. **Surface/Sidewalk:**
   - Construction boundary
   - All ICDs and interconnected CBs
   - Gutters (concrete and grass) and details as required. For concrete gutters, requirements for deep and highback gutters should be indicated.
   - Cross Sections and details as required. These can include spillover elevations, clearance details for overland flows, etc.

ii. **Sanitary:**
   - Sanitary sewer manholes requiring seals or one-hole manhole lids must be identified.

iii. **Storm:**

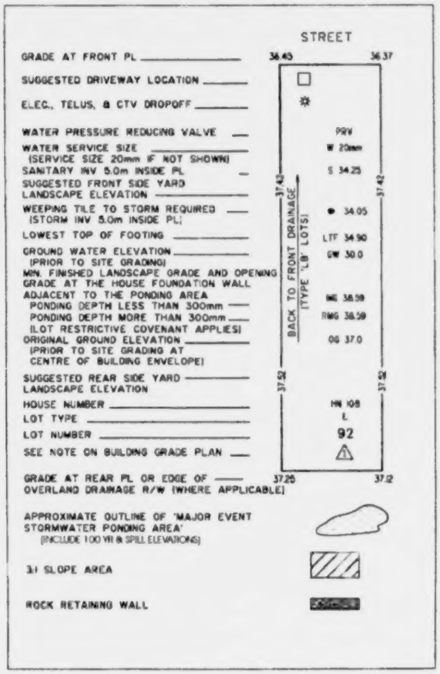
- All ICDs and interconnected CBs
- Details must be provided for R100 ICDs
- Piping-layout, pipe type, class and size, bedding
- All piping to be rubber gasketed unless approved otherwise
- Special hydraulic requirements (benching details, HGLs, etc)

iv. **Storm Drainage:**

- Drainage Areas and Sizes. Drainage areas must agree with approved stormwater report.
- Drainage Boundaries
- Table for Release Rates (L/s/ha) and trunk design
- ICDs and interconnected CBs

v. **Building Grade Plan:**

- Weeping tile requirements. Weeping tile is required on all lots unless water table readings are submitted showing that weeping tile is not required.
- Trap Lows and information (100 year and spill elevations and depths)
- MGs/RMGs for affected lots
- Side yard elevations to ensure overland flow does not spill through private property.
- HGLs as required


STREET
GRADE AT FRONT PL
36.45
36.37
SUGGESTED DRIVEWAY LOCATION
ELEC., TELUS, & CTV DROPOFF
WATER PRESSURE REDUCING VALVE
PRV
WATER SERVICE SIZE (SERVICE SIZE 20mm IF NOT SHOWN)
W 20mm
SANITARY INV 5.0m INSIDE PL
S 34.25
SUGGESTED FRONT SIDE YARD LANDSCAPE ELEVATION
37.43
37.42
WEEPING TILE TO STORM REQUIRED (STORM INV 5.0m INSIDE PL)
34.05
LOWEST TOP OF FOOTING
LTF 34.90
GROUND WATER ELEVATION (PRIOR TO SITE GRADING)
GW 30.0
MIN. FINISHED LANDSCAPE GRADE AND OPENING GRADE AT THE HOUSE FOUNDATION WALL ADJACENT TO THE PONDING AREA
PONDING DEPTH LESS THAN 300mm
MG 38.59
PONDING DEPTH MORE THAN 300mm (LOT RESTRICTIVE COVENANT APPLIES)
RMG 38.59
ORIGINAL GROUND ELEVATION (PRIOR TO SITE GRADING AT CENTRE OF BUILDING ENVELOPE)
OG 37.0
BACK TO FRONT DRAINAGE
(TYPE 'LB' LOTS)
SUGGESTED REAR SIDE YARD LANDSCAPE ELEVATION
37.52
37.52
HOUSE NUMBER
HN 108
LOT TYPE
L
LOT NUMBER
92
SEE NOTE ON BUILDING GRADE PLAN
GRADE AT REAR PL OR EDGE OF OVERLAND DRAINAGE R/W (WHERE APPLICABLE)
37.25
37.12
APPROXIMATE OUTLINE OF 'MAJOR EVENT STORMWATER PONDING AREA' (INCLUDE 100 YR & SPILL ELEVATIONS)
3:1 SLOPE AREA
ROCK RETAINING WALL

vi. **Overland:**

- Subdivision phase and construction boundary
- Trap Low Storage Table (volume, depth & elevation for 100 year and spill conditions)
- Minimum Building Opening Elevation (MGs) & Restrictive Covenants (RMGs)
- Q,v,d's for all critical segments (into and out of trap lows, roads, gutters, etc.). Depth-velocity guidelines (Alberta) must be met.
- ICDs and any interconnected CBs
- Details/Cross-sections for spill elevations as required.
- Overland Escape Routes must be clearly delineated.

vii. **Erosion & Sediment Control:**

- Erosion control features for subdivision phase and overall drainage area (as required).
- Details for erosion control features

viii. **Block Profiles:**

- ICDs and interconnected CBs
- Original ground elevations
- Storm pipe design and details
- High point and low point elevations for trap lows should be shown for quicker review. Spill elevations and depths for trap lows must agree with approved stormwater report.
- Concrete gutter requirements and details (ie. deep, highback, etc.)

ix. **Details:** (as required)

- Gutters
- Grass swales
- Structures (ie. outfalls, etc.)
- Water quality enhancements (as required)
- BMP designs (as required)
- Geotechnical designs (as required)

x. No surface approval will be given until the subdivision stormwater management report (SWMR) has been submitted, reviewed and approved. Three weeks minimum is required for report review. Underground approval is at the discretion of Wastewater & Drainage. Wastewater & Drainage will return, without review, all final construction drawings for which a stormwater report has not been submitted and reviewed.

11.2.2 Stormwater Ponds

Engineering drawings for stormwater ponds should be submitted as a separate set of drawings from the subdivision drawings for the purpose of circulation. **All stormwater pond circulations must be submitted to Urban Development for internal circulation; Urban Development will also forward a copy of the drawings to Alberta Environment.**

11.2.2.1 Drawing Requirements

Several drawings are required for stormwater ponds. Where feasible, drawings may be combined. The drawings should include the following information:

i. **Storm Drainage:**
   - Drainage Areas and Sizes. Drainage areas must agree with approved stormwater report.
   - Drainage Boundaries
   - Table for Release Rates (L/s/ha) and trunk design
   - ICDs and interconnected CBs (as required)

ii. **Site/Overall:**
   - Pond-outline, bottom/NWL/HWL elevations, 100 year elevation if different than HWL
   - Sediment forebay(s)-design and volumes
   - Pond staging shown when permitted
   - Table showing stage, elevation, area and volume
   - Location of structures and monitoring panel
   - Pathway-location, width & subgrade requirements
   - Signage
   - Construction Boundary

iii. **Storm:**
   - Piping-layout, pipe type, class and size, bedding
   - All piping to be rubber gasketed unless approved otherwise
   - Location of structures (inlet/outlet, control) and monitoring panel
   - Special hydraulic requirements (benching details, HGLs, etc.)

iv. **Block Profiles**: (as required)

v. **Inlet Structures:**
   - Details, inverts
   - Gratings, bolting & coating
   - Rip Rap erosion protection

vi. **Catchbasins/Drain Inlets (for Dry Ponds):**

- Details, inverts
- Gratings, bolting & coating

vii. **Outlet Control Structure:**

- Bypass gate
- Weir wall
- Trash rack
- Orifice-material, size, elevations
- Discharge Table: stage-elevation-discharge (area and volume can also be included)
- Gratings (as required)

viii. **Subdrainage System:**

- Layout and details of subdrainage system

ix. **Contour:**

- Include contour plan and indicate pond bottom, NWL, HWL and 100 year elevations (if different than HWL).
- Include side slopes and bottom slopes (as required)
- Overland escape route and details (cross-section and longitudinal section)
- Cross sections
- Geotechnical requirements

x. **Monitoring Equipment:**

- Details of monitoring equipment and setup
- Elevations for alarms

xi. **Miscellaneous Details:** (as required)

- Water quality enhancements (as required)
- Geotechnical designs (as required)

xii. **Landscaping & Vegetation:**

- Details of perimeter landscaping and vegetation
- Details of pond landscaping and vegetation
- Details of benching and side slope changes
- Setbacks from utility easements must be maintained

xiii. **Irrigation:**

- Layout and details of irrigation system

xiv. Ponds must be constructed prior to or in conjunction with the first phase of development. Pond staging is **not** permitted for dry ponds; staging for wet ponds and wetlands requires the approval of Wastewater & Drainage. Wastewater & Drainage will return, without review, all pond construction drawings for which a pond stormwater report has not been submitted and reviewed.

11.2.3 Drainage & Site Servicing Plans (DSSPs)

11.2.3.1 Drawing Requirements

Drawing requirements are not generally as stringent for DSSPs as for subdivisions, unless the site is large and/or complicated. The drawings should include stormwater management information and details as described:

i. **Overall Servicing:**

- Overall site including property line, section, address, etc.
- Buildings, parking lots (paved and gravelled)
- Layout of storm and sanitary systems and connection(s) including manholes and CBs. Alberta plumbing code requirements must be met.
- Details of storm and sanitary system (pipe type, class, size, bedding)
- All ICDs and interconnected CBs; details must be provided for R100 ICDs
- Outlet control (service connection) and applicable details
- Hydraulic requirements (benching, HGLs, backwater valves, etc.)
- Minimum top of slab elevation(s) required for building(s)

ii. **Grading and Overland:**

- Off-site drainage areas and flow rates
- Adjacent properties and streets (show trap lows)
- Permitted release rate and any restrictions
- Storage volume calculations and requirements (100 year and proposed). All stormwater up to and including the 100 year design, must be maintained on site without flowing onto adjacent property or public property.
- Imperviousness and runoff coefficients as required
- Details of stormwater storage: trap lows (100 year and spill depth, elevation and volume), roof top (volume, design details), underground (volume, discharge), stormwater ponds (see **Section 11.2.2**), and evaporation ponds (see following section), and any other applicable details
- Water quality requirements and applicable details (as required)
- BMPs and applicable details (as required)

- Sediment and erosion control requirements and applicable details
- Grading showing landscaping, berms, escape routes, ponds, and applicable elevations. Details of the overland escape route to be provided. Stormwater must be contained on-site
- Other details (as required)
- Reference to applicable stormwater report(s)

iii. **Stormwater Ponds:**

- Pond drawings should follow the requirements in **Section 11.2.2**. Smaller and simpler ponds will require less details. Geotechnical requirements must be addressed. Monitoring equipment is not required.

iv. **Evaporation Ponds:**

- Evaporation pond drawings should follow the requirements in **Section 11.2.2** as required. Details pertaining to inlet/outlet control structures can generally be omitted. Geotechnical requirements must be addressed. Monitoring equipment is not required.

11.2.4 Special Projects and Contracts (SP)

11.2.4.1 Drawing Requirements

Drawing requirements for special projects and contracts should conform to the requirements for subdivisions, stormwater ponds, or drainage & site servicing plans as required. Refer to applicable sections. Contact Wastewater & Drainage for more information.

11.3 Inspections

Ongoing inspections by Wastewater & Drainage are required for subdivisions, stormwater ponds, and special projects and contracts during construction. The developer/consultant is also required to have their own inspectors on site. Contact Wastewater & Drainage Inspections Group for more information regarding inspections.

Drainage & Site Servicing Plans require inspections from the City of Calgary Development & Building Applications Department. Contact Development & Building Applications for more information.

11.4 Certificates

Construction Completion Certificates (CCC) and Final Acceptance Certificates (FAC) are required for subdivisions and stormwater ponds that that will ultimately be taken over by the City. Special projects and contracts also require CCCs and FACs. Prior to the issuance of certificates, all storm systems and ponds should be clean and functional. All required testing must be submitted and approved by the Wastewater & Drainage Inspections Group.

Drainage & Site Servicing Plans do not require CCCs or FACs since the properties are privately owned. However, any development permit conditions must be met.

Subdivisions and ponds require separate certificates. Maintenance periods may vary. Generally, a maintenance period of three years is required for new subdivisions and stormwater ponds. Wetlands and automatic control gate systems require a maintenance period of five years. Retrofit projects generally require a two year maintenance period. See **Section 6.1.10** for more information on maintenance periods for stormwater ponds.

11.5 As-Builts

11.5.1 Purpose

As part of the CCC and FAC process, as-builts are required for subdivisions, stormwater ponds, and special projects and contracts. All as-builts should be forwarded to Wastewater & Drainage Inspections Group for review and approval. Where required, the Inspections Group will forward the as-builts to other reviewing personnel. As-built items are being identified as essential and non-essential; details of the program are on-going. The Inspections Group should be contacted regarding requirements.

11.5.2 Subdivision

Contact Wastewater & Drainage Inspections Group for as-built requirements. To control grading for stormwater management, the following additional as-builts are required:

- As-built elevations of the critical spill locations for trap lows during construction. Locations that are not within tolerance must be corrected before the contractor leaves the site. An allowable tolerance of +/- 50 mm is required. Where the spill elevations of several trap lows in an area are similar, a tighter tolerance will be required to ensure overland flows spill in the required direction.
- Each lot adjacent to a trapped low where an MG or RMG elevation is indicated on the Building Grade Plan will show this requirement on the building grade slip issued to the builders. A "Minimum Finished Grade Elevation Certificate" prepared by a Professional Engineer or Alberta Land Surveyor must be submitted to the Development & Building Applications Department certifying that garage slab and house openings are above the MG or RMG elevation specified. This will be done as a pilot project and is subject to change.

11.5.3 Ponds

Stormwater ponds undergo a more extensive as-built review due to water quantity, water quality and safety requirements. Please refer to **Appendix J Stormwater Pond Check Sheets** for as-built and inspection requirements. As-builts must be forwarded to the Wastewater & Drainage Inspection Group (Sr. Inspector); the Inspection Group will forward the as-builts to the Stormwater Engineer for checking and coordination of other inspections (ie. electrical, field, etc.). Contact Wastewater & Drainage for further information.

11.5.4 Drainage & Site Servicing Plans

As-builts for stormwater ponds and evaporation ponds must be submitted to the Stormwater Engineer in Wastewater & Drainage. Otherwise, most DSSP sites do not require submission of as-builts unless specifically requested by Wastewater & Drainage. The owner must ensure that sufficient stormwater storage has been constructed to contain overland flows on site.

12.0 References

AMK Associates International Ltd., *"Dual Drainage Storm Water Management Model-Program Documentation and Reference Manual"*, 1996

Alberta Environmental Protection, "*Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage System*", 1997

Alberta Environmental Protection, *"Stormwater Management Guidelines for the Province of Alberta*", 1999

Alberta Environmental Protection, "Surface Water Quality Guidelines for Use in Alberta", November 1999

American Public Health Association, American Water Works Association, and Water Environment Federation, "*Standard Methods for the Examination of Water and Wastewater-20th Edition*", 1998

American Public Works, *"Urban Stormwater Management"*, Special Report No. 49, 1981

ASCE and CSCE, *"Best Management Practices for Municipal and Industrial Stormwater Control"*, 1994

ASCE and WEF, *"Design and Construction of Urban Stormwater Management Systems"*, WEF Manual of Practice FD-77 and ASCE Manual and Reports of Engineering Practice No. 77, 1992

Azous, Amanda L. and Horner, Richard R., "*Wetlands and Urbanization-Implications for the Future*", Final Report of the Puget Sound Wetlands and Stormwater Management Research Program, 1997

Bartoldus, Candy C., Garbisch, Edgar W. and Kraus, Mark L., "*Evaluation for Planned Wetlands-A Procedure for Assessing Wetland Functions and a Guide to Functional Design*", Environmental Concern Inc., 1994

Baudo, R., Giesy, J., and Muntau, H., "*Sediments: Chemistry and Toxicity of In-Place Pollutants*", 1990

BC Environment, "*Urban Runoff Quality Control Guidelines for The Province of British Columbia*", 1992

Center for Watershed Protection, *"Stormwater BMP Design Supplement of Cold Climates"*

Center for Watershed Protection, *"The Economics of Stormwater BMPs in the Mid-Atlantic Region"*, 1997

Center for Watershed Protection, *"Watershed Protection Techniques-Volume 2, Number 3"*, 1997

Chang, F.M., Kilgore, R.T., Woo., D.C., and Mistichelli, M.P., "*Energy Losses Through Junction Manholes-Volume I: Research Report and Design Guide"*, FHWA-RD-94-080, 1994

Chow, Ven te, *"Open Channel Hydraulics"*, 1959

City of Calgary, "*A Policy on Stormwater Lakes*", 1981

City of Calgary, "*Public Participation in the Development and Maintenance of the Calgary River Valley System*", CS90-44-01, 1990

City of Calgary, "*Technical Report on Dry Ponds*", 1988

City of Calgary, "*Wet Ponds: Policy Review*" OE-96-52, 1996

City of Calgary, "*Calgary Open Space Plan-DRAFT*", Calgary Parks & Recreation, 1999

City of Calgary, "*Calgary Open Space Plan-DRAFT FINAL*", Calgary Parks & Recreation, 2000

City of Calgary, "*Development Guidelines and Standard Specifications-Landscape Construction*", Calgary Parks & Recreation

City of Calgary, *"Integrated Pest Management Plan"*, Calgary Parks & Recreation, 1998

City of Calgary, *"Design Guidelines for Subdivisions"*, Engineering & Environmental Services Department, 1991

City of Calgary, *"Design Guidelines for Development Permits, Mechanical Site Plans and Solid Waste Services Plans"*, Engineering & Environmental Services Department, 1992

City of Calgary, *"Guidelines for Erosion & Sediment Control"*, Sewer Division, 1992

City of Calgary, *"ICD Testing Results"*, Sewer Division, 1995

City of Calgary, *"Comparison Between DDSWMM and SWMHYMO"*, Wastewater & Drainage, 2000

City of Calgary, "*Standard Specifications Sewer Construction*", Wastewater & Drainage, 2000

City of Edmonton, "*Design and Construction Standards-Volumes 1, 2 & 3*", 1999

Corrugated Steel Pipe Institute, *"Modern Sewer Design-Canadian Edition"*, 1996

CSCE and ASCE, *"Best Management Practices for Municipal and Industrial Stormwater Control"*, 1994

Eastlick, Kim, "*An Introduction to Wetlands Wastewater Treatment and Potential Western Canadian Applications-A Brief Technology Overview*"

Eastlick, Brian Kim, "*Constructing Wetlands for Water Quality Enhancement in Western Canada: Technical Literature Review*", 1993

Ettema, R., Jain, S.C., Kennedy, J.F., *"Hydraulic Design of Drop Structures-A State-of-the-Art Review"*, Iowa Institute of Hydraulic Research, 1982

Government of Canada, "*Fisheries Act*", Fisheries, 1991

Government of Canada, "*Fish Habitat Conservation and Protection-What the Law Requires*", Fisheries and Oceans, 1995

Government of Canada, "*Navigable Waters Protection Act*", 1985

Greenland International Consulting Inc., "*Storm Water Management Facility Maintenance Guide*", Job #97-G-1149, 1999

Haan, C.T., Barfield, B.J. and Hayes, J.C., *"Design Hydrology and Sedimentology for Small Catchments"*, 1994

Haestad Methods, *"1997 Practical Guide to Hydraulics and Hydrology"*, 1997

J.F. Sabourin & Associates Inc., *"SWMHYMO Storm Water Management Hydrologic Model-User's Manual"*, 1998

JNMacKenzie Engineering Ltd., *"Overland Flow Methodology"*, 1992

Kadlec, Robert H. and Knight, Robert L., "*Treatment Wetlands*", Lewis Publishers, 1996

Kassem, A. and Wisner, P., *"OTTSWMM-The University of Ottawa Storm Water Management Model"*, 1983

King County (Washington) Department of Public Works, "*Surface Water Design Manual*", 1994

Krenkel, Peter A. and Novotny, Vladimir, "*Water Quality Management*", 1980

Maine Department of Environmental Protection, *"Stormwater Management for Maine: Best Management Practices"*, 1995

Marsalek, J., *"Head Losses at Selected Sewer Manholes"*, NWRI 85-15, 1985

Marsalek, J. and Greck, B.J., *"Head Losses at Manholes with a 90^0 Bend"*, Canadian Journal of Civil Engineering 15, 851-858, 1988

Maryland Department of the Environment, "*Maryland Stormwater Design Manual-Volumes I & II-REVIEW DRAFT*", 1998

Massachusetts Department of Environmental Protection and Massachusetts Office of Coastal Zone Management, *"Stormwater Management-Volumes One and Two"*, 1997

Metropolitan Washington Council of Governments, *"A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone"*, 1992

Northern Virginia Planning District Commission, *"Nonstructural Urban BMP Handbook-A Guide to Nonpoint Source Pollution Prevention and Control through Nonstructural Measures"*, 1996

Northern Virginia Planning District Commission, *"Northern Virginia BMP Handbook: A Guide to Planning and Designing Best Management Practices in Northern Virginia"*, 1992

Northern Virginia Planning District Commission, *"Northern Virginia BMP Handbook Addendum: Sand Filtration Systems"*, 1996

Northern Virginia Planning District et al., *"Outlet Hydraulics of Extended Detention Facilities"*, 1989

Ohio Department of Natural Resources, *"Keeping Soil on Construction Sites: Best Management Practices"*, 1991

Ohio Department of Natural Resources, *"Rainwater and Land Development: Ohio's Standards for Stormwater Management Land Development and Urban Stream Protection"*, 1996

Ontario Concrete Pipe Association, *"Concrete Pipe Design Manual"*

Ontario Ministry of Environment and Energy, "*Stormwater Management Practices Planning and Design Manual*", 1994

Ontario Ministry of the Environment, "*Stormwater Management Planning and Design Manual-DRAFT FINAL*", 1999

Ontario Ministry of the Environment, *"Guidelines for Evaluating Construction Activities Impacting on Water Resources"*, 1995

Ontario Ministries of Natural Resources, Environment, Municipal Affairs and Transportation & Communications, et al., *"Guidelines on Erosion and Sediment Control for Urban Construction Sites"*, 1987

Paul Wisner & Associates Inc., *"INTERHYMO/OTTHYMO 89"*, 1989

Province of Alberta, "*Environmental Protection and Enhancement Act*", 1998

Province of Alberta, "*Environmental Protection and Enhancement Act-Activities Designation Regulation 211/96*", 1996

Province of Alberta, "*Environmental Protection and Enhancement Act-Approvals and Registrations Procedure Regulation 113/93*", 1993

Province of Alberta, "*Environmental Protection and Enhancement Act-Wastewater and Storm Drainage Regulation 119/93*", 1996

Province of Alberta, "*Environmental Protection and Enhancement Act-Wastewater and Storm Drainage (Ministerial) Regulation 120/93*", 1996

Province of Alberta, "*Municipal Government Act*", 1998

Province of Alberta, "*Public Lands Act*", 1998

Province of Alberta, "*Water Act*", 1998

Province of Alberta, "*Water Act-Water (Ministerial) Regulation 205/98*", 1998

Province of Alberta, "*Water Resources Act*", 1980

Reid Crowther & Partners Ltd., "*Discovery Ridge Sedimentation Pond No. 1 Design Brief-Revised*", May 1999

Reid Crowther & Partners Ltd., *"Stormwater Management Methodology"*, 1992

Rowney, A.C. and Macrae, C.R., *"QUALYMO User Manual-Release 2.2"*, 1994

Sawyer, Clair N. and McCarty, Perry L., "*Chemistry for Environmental Engineering*", 1978

Schueler, Thomas R., Anacostia Restoration Team, Department of Environmental Programs and Metropolitan Washington Council of Governments, "*Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Mid-Atlantic Region*", 1992

Stantec Consulting Ltd. (formerly IMC Consulting Group), *"Application of DDSWMM with EXTRAN Linkage"*, 1996

Strathcona County, *"Engineering Servicing Standards"*, 1998

United States Department of Agriculture, "*Ponds-Planning, Design, Construction*", 1982

United States Environmental Protection Agency, "*Protecting Natural Wetlands-A Guide to Stormwater Best Management Practices*", Office of Water, 1996

United States Environmental Protection Agency, "*Natural Wetlands and Urban Stormwater: Potential Impacts and Management*", Office of Wetlands, Oceans and Watersheds, 1993

United States Environmental Protection Agency, "*Storm Water Management for Construction Activities-Developing Pollution Prevention Plans and Best Management Practices*", Office of Water, 1992

Urban Drainage and Flood Control District (Denver, Colorado), *"Urban Storm Drainage Criteria Manual-Volumes 1, 2 and 3"*, 1999

U.S. Department of Transportation, *"Urban Drainage Design Manual-Hydraulic Engineering Circular No. 22"*, FHWA-SA-96-078, 1996

USDA-Natural Resource Conservation Service and the United States Environmental Protection Agency-Region III, "*A Handbook of Constructed Wetlands-Volume 1*"

Usher, Robyn and Scarth, Jonathan, "*Alberta's Wetlands: Water in the Bank!*", Environment Council of Alberta, 1990

Viessman, W., Knapp, J., Lewis, G., and Harbaugh, T., *"Introduction to Hydrology"*, 1977

Washington State Department of Ecology, *"Stormwater Management in Washington State-Volumes I, II, III, IV and V "*, 1999

Washington State Department of Ecology, *"Stormwater Management Manual for the Puget Sound Basin"*, 1992

Williams, James, *"Rules for Responsible Modelling"*, 1994

Appendix A Process for Application and Approval for Stormwater Ponds and Outfalls (EPEA)[15]

---

[15] Alberta Environment, "Process for the Application and Approval of Municipal Storm Drainage Activities", March 15, 2000

Process for the Application and Approval of Municipal Storm Drainage Activities – STORMWATER PONDS AND OUTFALLS under the *Alberta Environmental Protection and Enhancement Act (EPEA)*

Application to Director

The application consists of:

- a letter requesting an amendment to the City of Calgary's *Environmental Protection and Enhancement Act* Wastewater and Storm Drainage approval for the particular activity-stormwater pond, outfall, or stormwater pond and outfall;
- the master drainage plan (will be submitted prior to the final stormwater management report but forms part of application);
- the final stormwater management report which describes the pond and/or outfall and provides the following (Note: the items requested below ensure that the stormwater management report can be reviewed as a stand-alone document):

  for stormwater ponds
    - the location (both legal land description and municipal address);
    - the predicted water quality performance: a summary of total suspended solids removal (% removed and minimum size of particle);
    - the size of the catchment area;
    - a description of the complete hydraulics including groundwater and evaporation effects of the pond;
    - environmental design criteria – (aesthetic, wildlife habitat and passive recreational values);
    - a description of any downstream stormwater quality enhancement facilities;
    - the storage capacities of these downstream facilities;
    - the immediate (trunk) and ultimate (outfall) discharge locations of the pond; and
    - the receiving water body,

  NOTE: For ponds adjacent to watercourses, the Biophysical Impact Assessment Report must be submitted concurrently with the stormwater management report. For ponds which may be assessed as dams, the geotechnical report must be submitted concurrently with the stormwater management report.

  for outfalls
    - the capacity; and
    - the size of the catchment area.
- preliminary pond and/or outfall drawings

  for stormwater ponds these preliminary drawings must indicate:
    - the type of facility;
    - the location;
    - the size of the pond – both linear and volume; and
    - the proposed shape of the pond,

  for outfalls these preliminary drawings must indicate:
    - the location;
    - the size; and
    - the proposed configuration.

NOTE: For outfalls or any work involving instream or bank disturbances, an application must be made to Water Administration, Natural Resources Service, Alberta Environment under the *Water Act:* Contact person – Dwayne Manchak, 297-5891. A disposition under the Public Lands Act may also be required: contact person – Greg McAndrews, 297-7622.

(Information on submitting an application is found in Alberta Environment's *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems*, December 1997)

↓

Is the Application complete? - No ⇒ provide additional information as required

NOTE: The application cannot be processed until all of the above information has been received.

↓

Once application is received ⇒

- an application number is assigned for the project by Alberta Environment's Regulatory Approval Centre (RAC);

Is the Application complete? - Yes ⇒

- a draft advertisement is prepared and sent by RAC to the applicant (The City of Calgary) to review for accuracy and then publish once, at the applicant's expense, in the local newspapers.

↓

- There is a 30 day Public Notification period following the advertisement, during which time members of the public can file Statement of Concerns (SOC's) regarding the project.
- These SOC's are submitted to Alberta Environment. Those SOC's which are considered to be valid under the *Environmental Protection and Enhancement Act,* that is, have been submitted by an individual who is directly affected, are forwarded to the applicant.
- It is the applicant's (The City of Calgary's) responsibility to address these concerns to the satisfaction of the person who filed the SOC.
  - A written description must be submitted by the applicant to Alberta Environment detailing when and how each concern was addressed. Alberta Environment reviews this description and decides whether each concern was satisfactorily addressed. An amending approval is not issued until all outstanding issues concerning the project are resolved to the satisfaction of Alberta Environment. Note: Not all concerns will result in changes to the proposed design.
  - Each person who has filed a statement of concern, still maintains the right to appeal the amending approval once it has been issued whether or not their concerns were adequately addressed.
- If there are a sufficient number of valid SOC's filed, the Director of Environmental Service, Alberta Environment, can order a public meeting to be held by the applicant to address the issues raised.

↓

- During the 30 day Public Notification period, the application is reviewed for technical content and deficiencies.
- Final construction drawings for the proposed stormwater pond and/or outfall should be submitted to Municipal Approvals and/or Water Resources, Alberta Environment during this time to resolve any questions on the proposed design.

NOTE: The approval process cannot continue until all of the above steps have been completed.

↓

Once the public meeting has been held (if applicable), the technical content and deficiencies are resolved (if any), and all SOC's are satisfactorily addressed, the Director decides whether or not to issue the amending approval.

↓

An amending approval is issued for a new pond and the pond is added to the existing list of projects (appended to Table 12, Appendix IV of The City of Calgary Wastewater and Storm Drainage approval 95-MUN-317).

- A letter of acknowledgement is issued for an outfall listed in Table 11 or a pond listed in Table 12 of The City of Calgary's Wastewater approval 95-MUN-317, The letter of acknowledgement indicates that the plans and specifications for the stormwater pond and/or outfall have been reviewed and are satisfactory to Alberta Environment.
- Those persons who filed SOC's, which were considered to be valid, are sent a copy of the amending approval.
- Objections to the Notice of Decision for a project can be filed with the Environmental Appeal Board by those who submitted SOC's if they remain dissatisfied with a project (i.e. an appeal to the amending approval is filed). It is in every stakeholder's best interest to have all concerns addressed at the pre-approval stage to minimize the time-frame to approval.

Note: For projects requiring application under both EPEA and the Water Act, approvals will be issued concurrently from Environmental Service and Natural Resources Service.

Appendix B Storm Retention Calculations for Drainage & Site Servicing Plans

Storm Retention Calculations Based on Rational Method Design

The following is the method Wastewater & Drainage utilizes to check storm sewer retention systems for Drainage & Site Servicing Plans (DSSPs) that are based on the Rational Method Design (where permitted).

Retention

Q1 = allowable discharge to main (L/s)
Q_a = actual discharge to main from retention area ($Q_a \le Q1$)
C1 = runoff coefficient used to design public main; usually given at the time of the DP (C)
C1' = runoff coefficient of discharge
C2 = actual runoff coefficient from site, including future development. Refer to **Section 4.2.2.3** for runoff coefficients
i = intensity (82.55 mm/hr)
A = area of site (ha)
n = roughness coefficient (PVC=0.011, concrete=0.013)
H = head on pipe [(top of pond elevation) – (pipe invert + ½ pipe dia.)] (m)
V100 = storage volume required for 1:100 year event (m^3)
SVF = storage volume factor

Hydraulic Slope

HS = hydraulic slope
H1 = pipe obvert elevation at end of retention system (pipe invert + diameter) (m)
H2 = top of pond/trap low elevation (m)
L = length of retention pipe (from centre of manhole to end of pipe)

Steps

1) Calculate C2:

$$C2 = \frac{(1.0 \times \text{Roof area})+(0.9 \times \text{Pavement area})+(0.5 \times \text{Gravel area})+(0.3 \times \text{Landscaping area})}{A}$$

2) Calculate Q1:

$$Q1 = C1 \times 82.55 \times A \times 2.78 \text{ (L/s)}$$

3) Calculate HS:

$$HS = \frac{H2 - H1}{L}$$

4) Calculate Q_a:

a) Manning's Equation: $Q_a = [(1/n) \times (\text{pipe dia.}/4)^{2/3} \times HS^{1/2} \times (\pi(\text{pipe dia.})^2/4)] \times 1000$

b) ICDs: (see Section 3.3.5.2)

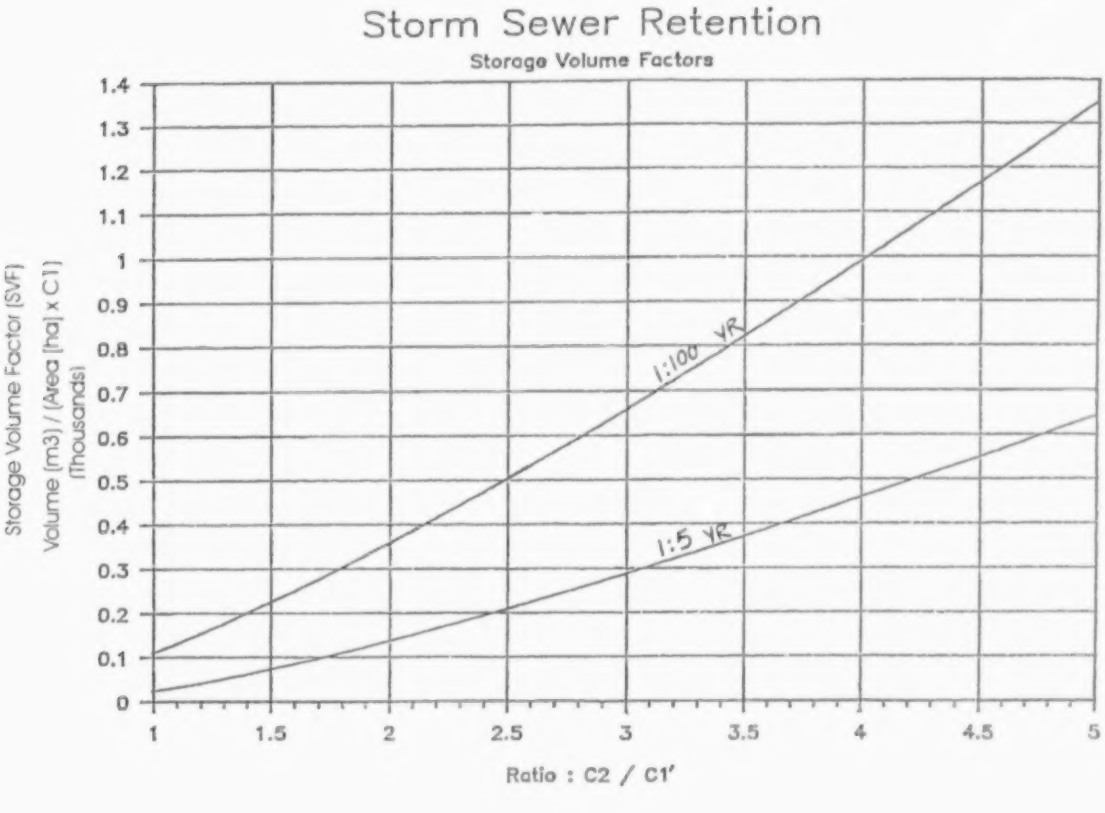
R30 ICD	$Q_a = 17.10 /H$
R50 ICD	$Q_a = 30.05 /H$
R70 ICD	$Q_a = 49.4 /H$
R100 ICD	$Q_a = 89.8 /H$

5) Calculate C1':

$$C1' = Q_a/(82.55 \times A \times 2.78)$$

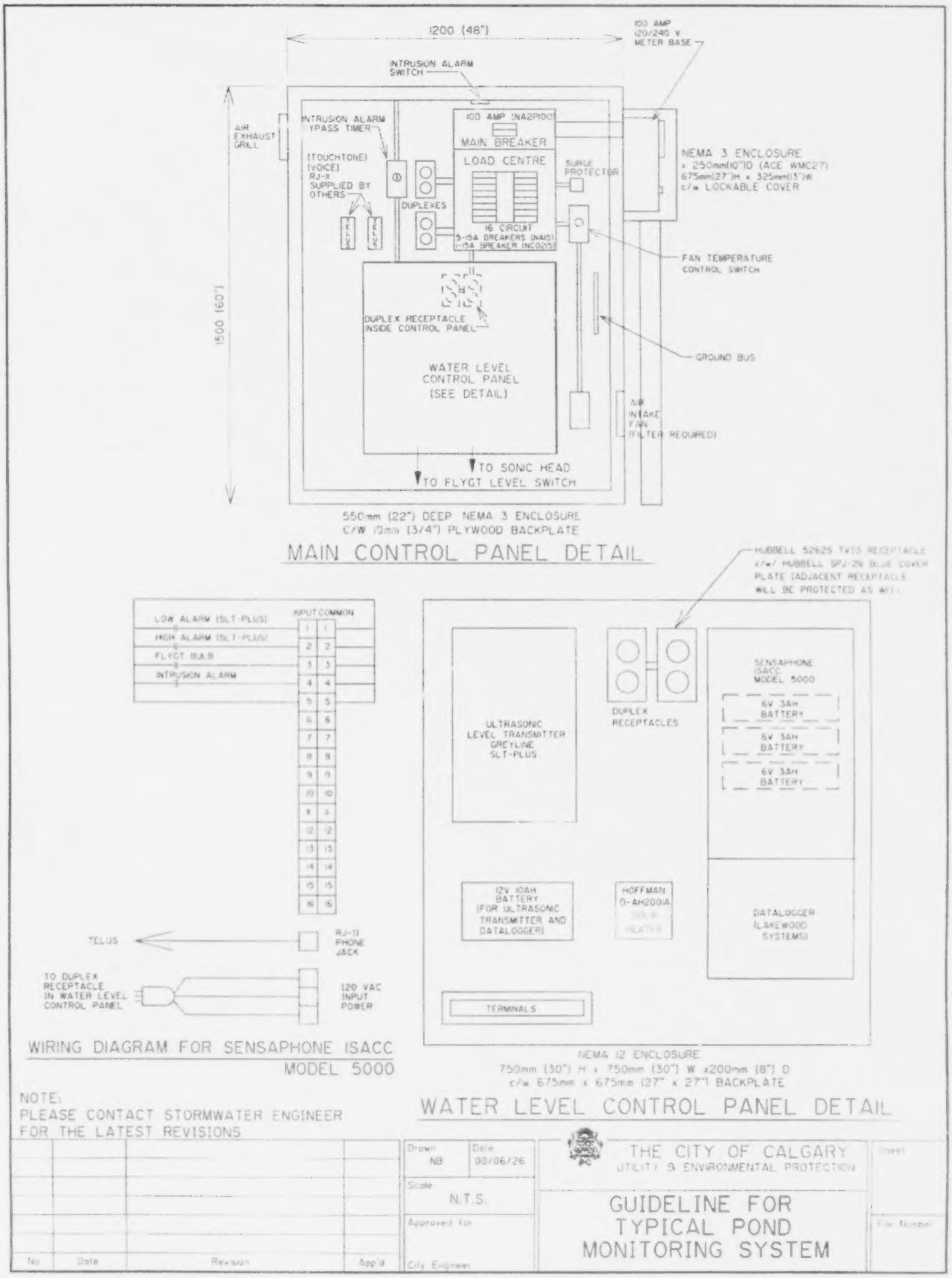
6) Determine Storage Volume Factor (SVF):

i. Determine C2/C1'
ii. Look up SVF from graph below



7) Determine V100: $V100 = SVF \times A \times C1' \times 1000\ (m^3)$

Appendix C Monitoring Equipment for Ponds



1200 (48")
100 AMP 120/240 V METER BASE
INTRUSION ALARM SWITCH
AIR EXHAUST GRILL
INTRUSION ALARM BYPASS TIMER
(TOUCHTONE) (VOICE) RJ-11 SUPPLIED BY OTHERS
TELUS
TELUS
DUPLEXES
100 AMP (NA2P100)
MAIN BREAKER
LOAD CENTRE
16 CIRCUIT
5-15A BREAKERS (NA15)
1-15A BREAKER (NC0215)
SURGE PROTECTOR
NEMA 3 ENCLOSURE
x 250mm(10")D (ACE WMC27)
675mm(27")H x 325mm(13")W
c/w LOCKABLE COVER
FAN TEMPERATURE CONTROL SWITCH
1500 (60")
DUPLEX RECEPTACLE INSIDE CONTROL PANEL
GROUND BUS
WATER LEVEL CONTROL PANEL (SEE DETAIL)
AIR INTAKE FAN (FILTER REQUIRED)
TO SONIC HEAD
TO FLYGT LEVEL SWITCH
550mm (22") DEEP NEMA 3 ENCLOSURE
C/W 19mm (3/4") PLYWOOD BACKPLATE
INPUT COMMON
LOW ALARM (SLT-PLUS)
HIGH ALARM (SLT-PLUS)
FLYGT B.A.B
INTRUSION ALARM
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
TELUS
RJ-11 PHONE JACK
TO DUPLEX RECEPTACLE IN WATER LEVEL CONTROL PANEL
120 VAC INPUT POWER
HUBBELL 52625 TV55 RECEPTACLE c/w HUBBELL SPJ-26 BLUE COVER PLATE (ADJACENT RECEPTACLE WILL BE PROTECTED AS WELL
ULTRASONIC LEVEL TRANSMITTER GREYLINE SLT-PLUS
DUPLEX RECEPTACLES
SENSAPHONE ISACC MODEL 5000
6V 3AH BATTERY
6V 3AH BATTERY
6V 3AH BATTERY
12V 10AH BATTERY (FOR ULTRASONIC TRANSMITTER AND DATALOGGER)
HOFFMAN D-AH2001A SPACE HEATER
DATALOGGER (LAKEWOOD SYSTEMS)
TERMINALS
NEMA 12 ENCLOSURE
750mm (30") H x 750mm (30") W x200mm (8") D
c/w 675mm x 675mm (27" x 27") BACKPLATE
No Date Revision App'd
Drawn NB
Date 00/06/26
Scale N.T.S.
Approved For
City Engineer
THE CITY OF CALGARY
UTILITY & ENVIRONMENTAL PROTECTION
Sheet
File Number

MAIN CONTROL PANEL DETAIL

WIRING DIAGRAM FOR SENSAPHONE ISACC MODEL 5000

WATER LEVEL CONTROL PANEL DETAIL

NOTE:
PLEASE CONTACT STORMWATER ENGINEER
FOR THE LATEST REVISIONS

GUIDELINE FOR
TYPICAL POND
MONITORING SYSTEM

NOTES

1. ALL WORK TO BE DONE IN ACCORDANCE WITH CANADIAN ELECTRICAL CODE.
2. HIGH LEVEL REGULATOR SWITCH AND ULTRASONIC LEVEL TRANSMITTER SHALL BE CONNECTED TO THE SENSAPHONE ISACC 5000 AUTODIALER. THE ULTRASONIC LEVEL TRANSMITTER SHALL ALSO BE WIRED TO THE DATALOGGER.
3. THE SENSAPHONE ISACC 5000 AUTODIALER SHALL BE PROGRAMMED TO DIAL OUT ON THE FOLLOWING CONDITIONS:
    - (i) ULTRASONIC-POND FILLING (LOW WATER LEVEL*) ALARM AT ELEVATION_____m.
      * POND BOTTOM FOR DRYPOND; NWL+0.1m FOR WETPONDS AND WETLANDS
    - (ii) ULTRASONIC-HIGH WATER LEVEL (HWL) ALARM AT ELEVATION ______m.
    - (iii) REGULATOR SWITCH-HIGH WATER LEVEL (HWL) ALARM AT ELEVATION _____m. AS A BACKUP SYSTEM TO THE ULTRASONIC LEVEL MONITOR.
    - (iv) POWER FAILURE CONDITION. (THE AUTODIALER AND THE ULTRASONIC UNIT MUST BE ON THE SAME BREAKER.)
    - (v) INTRUSION CONDITION.
4. THE CONTRACTOR SHALL ARRANGE FOR INSTALLATION OF TWO TELEPHONE LINES TO THE CONTROL PANEL ENCLOSURE BY TELUS. BOTH LINES MUST BE SUITABLE FOR VOICE TOUCH-TONE COMMUNICATION. EACH RJ-11 BOX MUST BE LABELLED WITH PROPER PHONE NUMBER.
5. THE CONTRACTOR SHALL INSTALL THE LEVEL TRANSMITTERS (ULTRASONIC LEVEL SENSOR AND REGULATOR SWITCH) IN APPROPRIATE LOCATIONS. THE REGULATOR SWITCH MUST BE SECURED IN AN AREA SUBJECT TO MINIMAL WATER TURBULENCE OUTSIDE THE TRASH RACK AND THE ULTRASONIC LEVEL SENSOR MUST BE LOCATED SUCH THAT THERE IS 0.3m OF RADIAL CLEARANCE PER 3.0m DEPTH IN THE CONTROL CHAMBER. (NO INTERFERENC WITH TRASH RACK, WALLS ETC.)
   THE UNIT SHOULD BE MOUNTED TO THE CEILING AND ABOVE THE LEVEL OF THE WEIR WALL. A MINIMUM CLEARANCE OF 0.50m IS REQUIRED BETWEEN THE BOTTOM OF THE UNIT AND THE TOP OF THE WEIR WALL (PWL) TO ACCOMMODATE THE SENSOR'S DEAD ZONE (BLANKING DISTANCE).
6. THE CONTRACTOR SHALL ENSURE ALL NECESSARY EQUIPMENT CAN BE INSTALLED IN THE EQUIPMENT ENCLOSURES.
7. THE CONTRACTOR SHALL ENSURE PROPER OPERATION OF THE DATA MONITORING AND DATALOGGING EQUIPMENT. THE ULTRASONIC LEVEL SENSOR MUST BE CALIBRATED. ALL ALARM CONDITIONS MUST BE TESTED.
8. INSTALLATION AND OPERATING MANUALS MUST BE SUPPLIED.
9. THE CONTRACTOR MUST ENSURE THAT THE ALARM SYSTEM IS TIED INTO THE ANNUNCIATOR SYSTEM AT THE MANCHESTER ENGINEERING EMERGENCY COMMUNICATION CENTRE (E.E.C.C.). CALIBRATION AND TESTING OF EQUIPMENT TO BE COMPLTETED BY SIMARK CONTROLS.
   CONTACT: CALVIN HEINRICHS (CITY OF CALGARY)
   268-3872
   THE WASTEWATER & DRAINAGE DESIGN SECTION MUST BE FORWARDED WITH THE PHONE NUMBERS FOR THE DATALOGGER AND THE AUTODIALER.
   CONTACT: CHRISTY LYON (CITY OF CALGARY)
   268-5528
10. CONTACTS:

KEVIN APPELHOF	DON HLIBKA
SIMARK CONTROLS	LAKEWOOD SYSTEMS
236-0580 (CALGARY)	462-9110 (EDMONTON)
FOR AUTODIALER AND ULTRASONIC	FOR DATALOGGER

11. THE MINIMUM MAINTENANCE PERIOD SHALL BE 2 YEARS FOR CITY OF CALGARY RETROFIT PROJECTS AND 3 YEARS (FOR FINAL ACCEPTANCE CERTIFICATE) FOR NEW SUBDIVISIONS UNLESS SPECIFIED OTHERWISE.

NOTE:
PLEASE CONTACT STORMWATER ENGINEER FOR THE LATEST REVISIONS

No.	Date	Revision	App'd

Drawn: NB
Date: 00/06/26
Scale
Approved for
City Engineer

THE CITY OF CALGARY
UTILITY & ENVIRONMENTAL PROTECTION

GUIDELINE FOR
TYPICAL POND
MONITORING SYSTEM

Sheet
File Number

LIST OF MATERIALS

MAIN CONTROL PANEL

1. MAIN CONTROL PANEL: NEMA 3 ENCLOSURE 1500mm (60") H x 1200mm (48") W x 550mm (22") D c/w 19mm (3/4") PLYWOOD BACK PLATE.
   ENCLOSURE MUST BE VENTED. AIR INTAKE FAN MUST HAVE A FILTER.
2. 100 AMP METER BASE:
3. METER BASE ENCLOSURE: NEMA 3 ENCLOSURE 675mm (27") H x 325mm (13") W x 250mm (10") D (ACE WMC27) c/w LOCKABLE COVER.
4. MAIN CIRCUIT BREAKER: NEMA 1 BE108-16 OR APPROVED EQUIVALENT.
5. 100 AMP MAIN BREAKER: TYPE NA2P100.
6. BREAKERS: A MINIMUM OF FIVE 15A BREAKERS (TYPE NA15). GROUND FAULT INTERRUPTER CIRCUIT BREAKERS (GFIC) ARE NOT TO BE USED.
7. SURGE PROTECTOR: SQUARE D MODEL SDSA1175 c/w ONE 15A BREAKER (NC0215)
8. INTRUSION ALARM BYPASS TIMER: INTERMATIC TIME SWITCH F30M.
9. FAN TEMPERATURE CONTROL SWITCH: HOFFMAN A-TEMNO.
10. DUPLEX RECEPTACLES: A MINIMUM OF TWO.
11. TELEPHONE: TWO WALL-MOUNTED TOUCHTONE RJ-11 JACKS (VOICE).
12. GROUND BUS

WATER LEVEL CONTROL PANEL

1. WATER LEVEL CONTROL PANEL: NEMA 12 750mm (30") H x 750mm (30") W X 200mm (8") D c/w 675mm x 675mm (27" x 27") BACKPLATE.
2. ULTRASONIC LEVEL TRANSMITTER: SIMARK GREYLINE SLT-PLUS OR APPROVED EQUIVALENT WITH 12V 10AH BATTERY BACKUP.
3. AUTODIALER: SENSAPHONE ISACC MODEL 5000 c/w BATTERY BACKUP
   ALTERNATIVES WILL NOT BE ACCEPTED.
4. HEATER: HOFFMAN D-AH2001A 200W
5. TWO DUPLEX RECEPTACLES -HUBBELL 5262S TVSS RECEPTACLE (ONE) c/w HUBBELL SPJ-26 BLUE COVER PLATE (ONE)
6. LAKEWOOD DATALOGGER: ONE OF TWO OPTIONS REQUIRED:
   OPTION A (COMPONENT LEVEL - ASSEMBLY REQUIRED)
      UL-16E ULTRA-LOGGER 32K
      UL-16TBE TERMINAL BOARD
      ULM-2412 INTERNAL MODEM (SET TO 1200 BAND)
      IP-420F 4-20mA INPUT PLUG WITH FILTER
      IP-P POWER INPUT PLUG
      QTY (5): R-XP RX EXPANSION CONNECTORS (COM.CHG.MOD.2-ALG)
      LE8409 COMMISSIONING CONTRACT.
   OPTION B (TURN-KEY)
      RX-2 DATALOGGER 32K
      RX-ACC ADAPTOR
      ULM 2412R MODEM (SET TO 1200 BAND)
      IP420F 4-20mA INPUT PLUG WITH FILTER
      LE8409 COMMISSIONING CONTRACT

MISC

1. ULTRASONIC LEVEL SENSOR: SIMARK GREYLINE PZ25T OR APPROVED EQUIVALENT.
2. HIGH LEVEL REGULATOR SWITCH: FLYGT ENM-10.
3. CABLE AS REQUIRED.

NOTE:
PLEASE CONTACT STORMWATER ENGINEER FOR THE LATEST REVISIONS

No.	Date	Revision	App'd

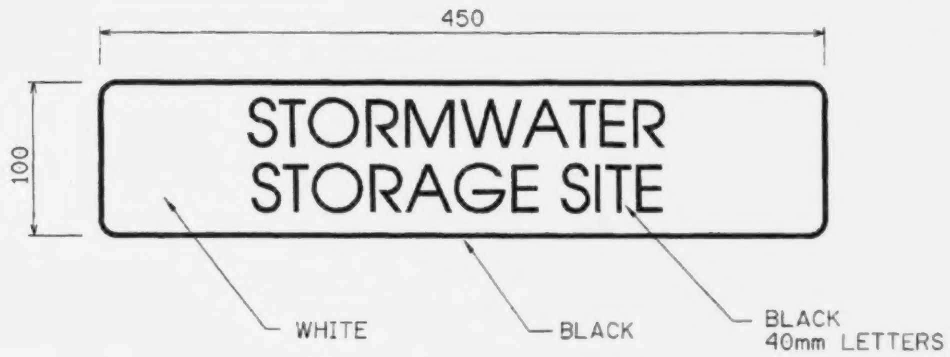
Drawn NB
Date 00/06/26
Scale
Approved for
City Engineer

THE CITY OF CALGARY
UTILITY & ENVIRONMENTAL PROTECTION

GUIDELINE FOR
TYPICAL POND
MONITORING SYSTEM

Sheet
File Number

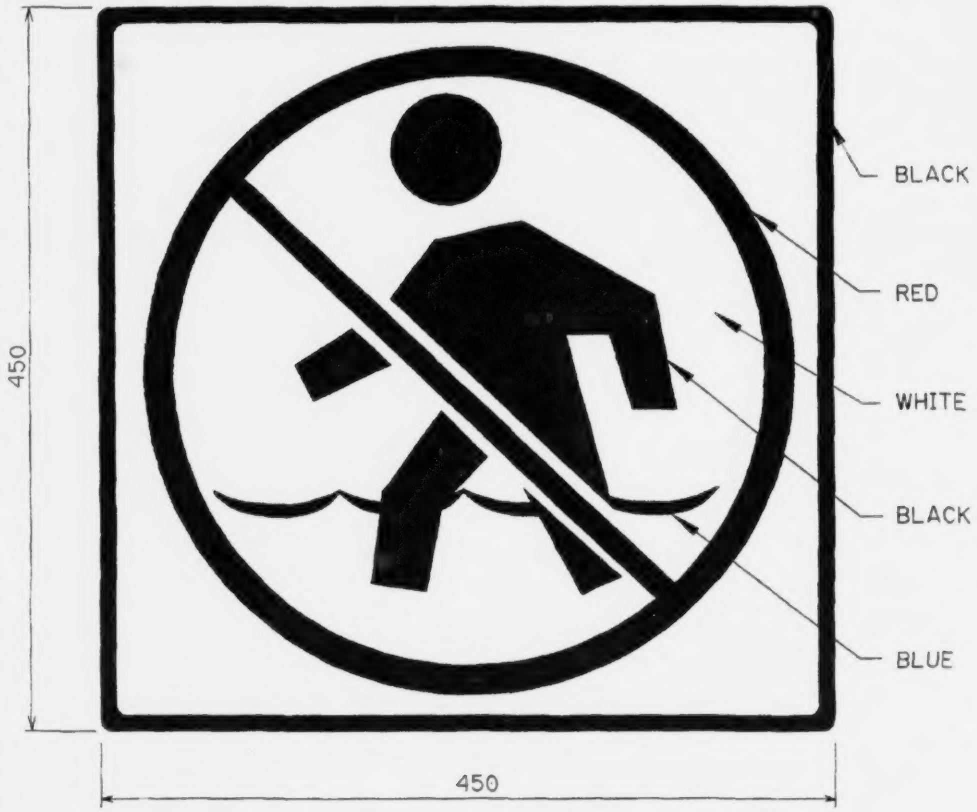
Appendix D Signage for Ponds


450
100
STORMWATER
STORAGE SITE
WHITE
BLACK
BLACK
40mm LETTERS

NOTE:
- TO ACCOMPANY SIGNS NO. 200, 300, 400 & 500
- COLOUR TO BE ENGINEER GRADE SCOTCHLITE

DIMENSIONS ARE MILLIMETRES UNLESS OTHERWISE NOTED METRIC

No.	Date	Revision	App'd	Drawn LC Date 98/09/14 Checked Scale N.T.S. Approved by Prince	THE CITY OF CALGARY ENGINEERING AND ENVIRONMENTAL SERVICES DEPARTMENT **STORMWATER STORAGE SITE** **SIGN 100**	Sheet 57 File Number 452.1043.001



NOTE:
* COLOUR TO BE ENGINEER GRADE SCOTCHLITE

DIMENSIONS ARE MILLIMETRES UNLESS OTHERWISE NOTED METRIC

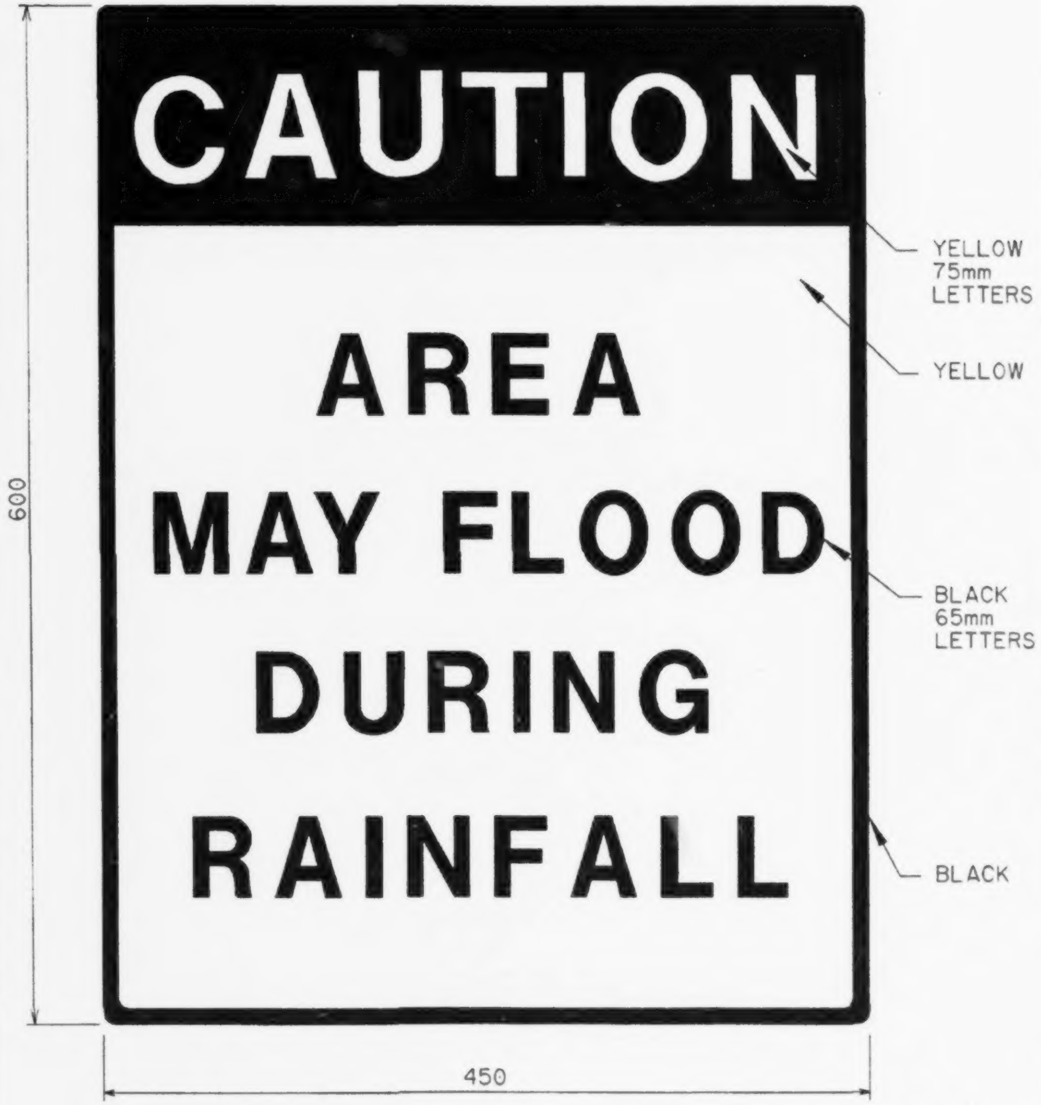
No.	Date	Revision	App'd

Drawn LC Date 98/09/14 Checked
Scale N.T.S.
Approved by

THE CITY OF CALGARY
ENGINEERING AND ENVIRONMENTAL SERVICES DEPARTMENT

STORMWATER STORAGE SITE
SIGN 200

Sheet **57A**
File Number 452.1043.002


CAUTION
AREA
MAY FLOOD
DURING
RAINFALL
YELLOW 75mm LETTERS
YELLOW
BLACK 65mm LETTERS
BLACK
600
450

NOTE:
- SIGNS WILL BE PLACED AT ACCESS ENTRANCE TO THE STORM IMPOUNDMENT AS INDICATED BY THE CITY ENGINEER.
- COLOUR TO BE ENGINEER GRADE SCOTCHLITE.

DIMENSIONS ARE MILLIMETRES UNLESS OTHERWISE NOTED METRIC

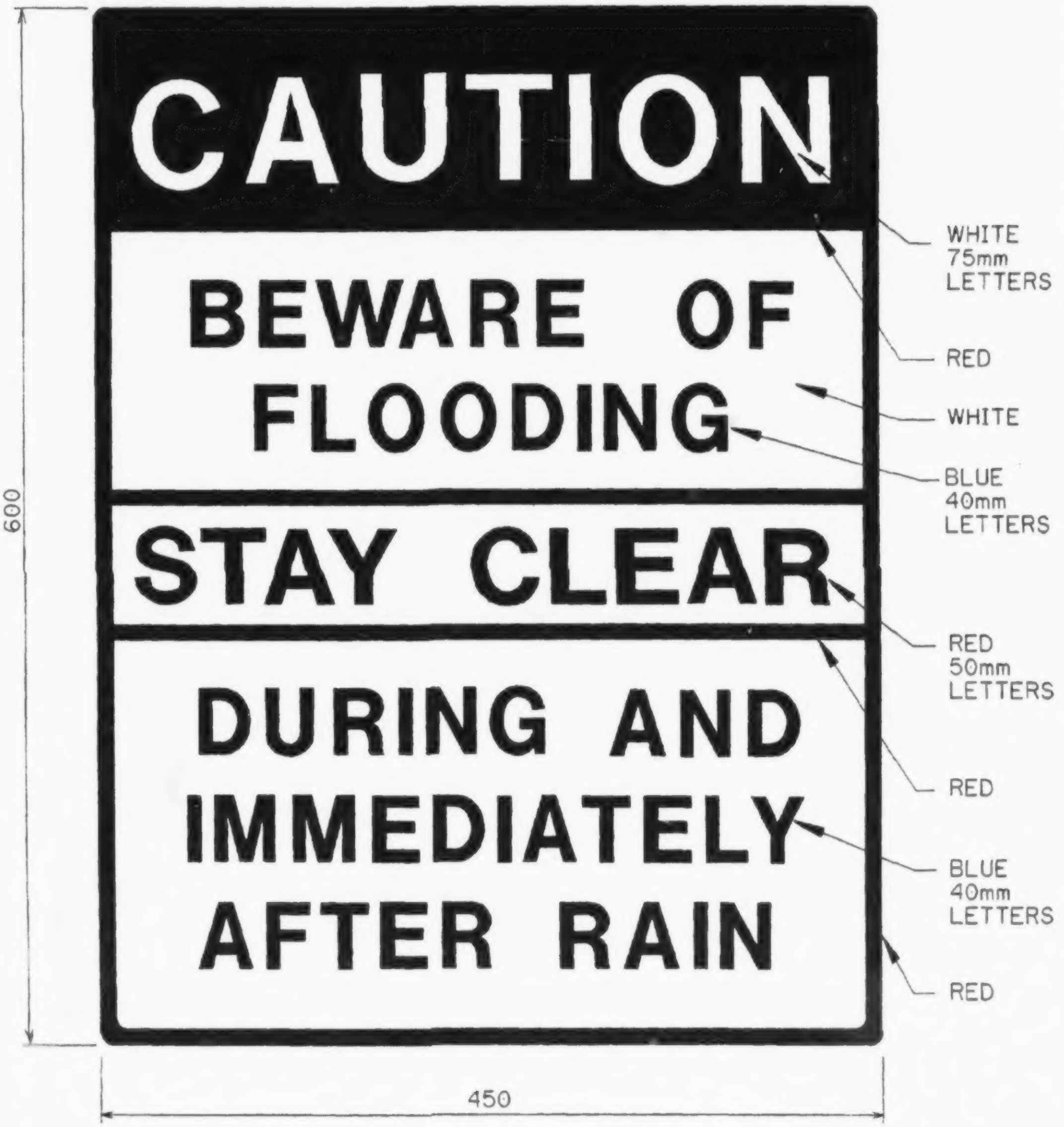
No	Date	Revision	App'd

Drawn LC
Date 99/09/14
Checked
Scale N.T.S.
Approved by The Engineer

THE CITY OF CALGARY
ENGINEERING AND ENVIRONMENTAL SERVICES DEPARTMENT

STORMWATER STORAGE SITE
SIGN 300

Sheet 57B
File Number 452.1043.003


CAUTION
BEWARE OF FLOODING
STAY CLEAR
DURING AND IMMEDIATELY AFTER RAIN
WHITE 75mm LETTERS
RED
WHITE
BLUE 40mm LETTERS
RED 50mm LETTERS
RED
BLUE 40mm LETTERS
RED
600
450

NOTE:
- SIGNS WILL BE PLACED AT ACCESS ENTRANCE TO THE STORM IMPOUNDMENT AS INDICATED BY THE CITY ENGINEER.
- COLOUR TO BE ENGINEER GRADE SCOTCHLITE.

DIMENSIONS ARE MILLIMETRES UNLESS OTHERWISE NOTED METRIC

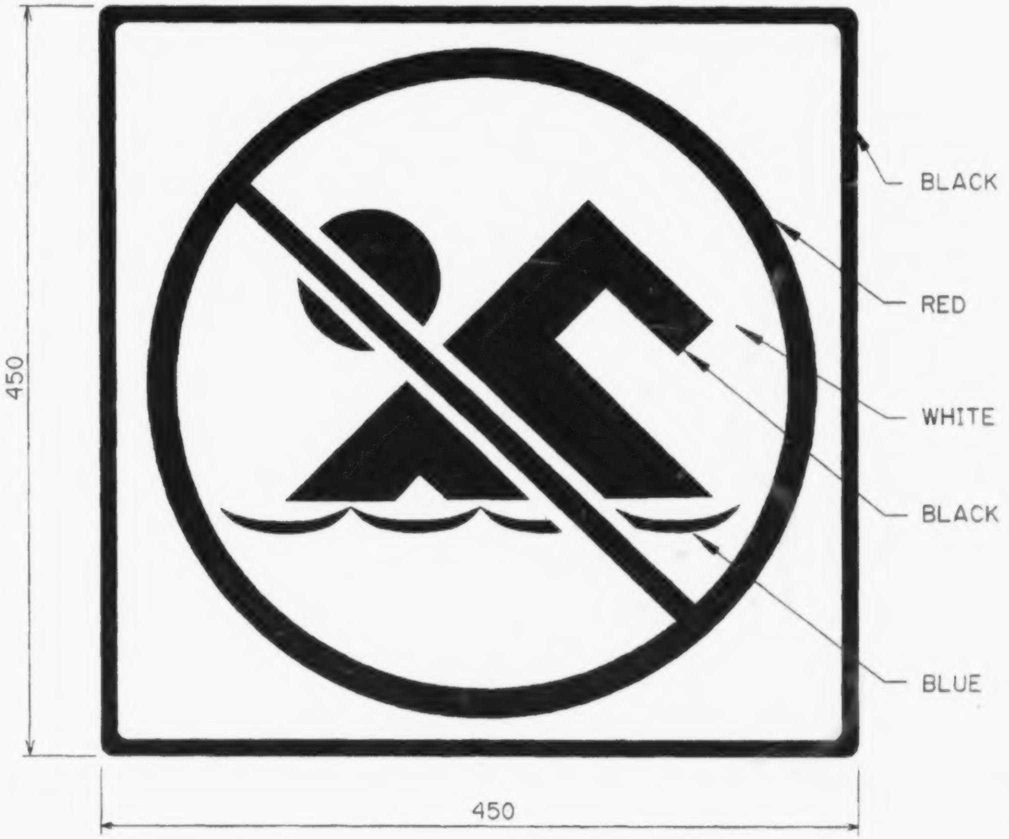
No.	Date	Revision	App.

Drawn LC
Date 99/09/14
Checked
Scale N.T.S.
Approved by

THE CITY OF CALGARY
ENGINEERING AND ENVIRONMENTAL SERVICES DEPARTMENT

STORMWATER STORAGE SITE
SIGN 400

Sheet 57C
File Number 452.1043.004



NOTE:
- COLOUR TO BE ENGINEER GRADE SCOTCHLITE

DIMENSIONS ARE MILLIMETRES UNLESS OTHERWISE NOTED METRIC

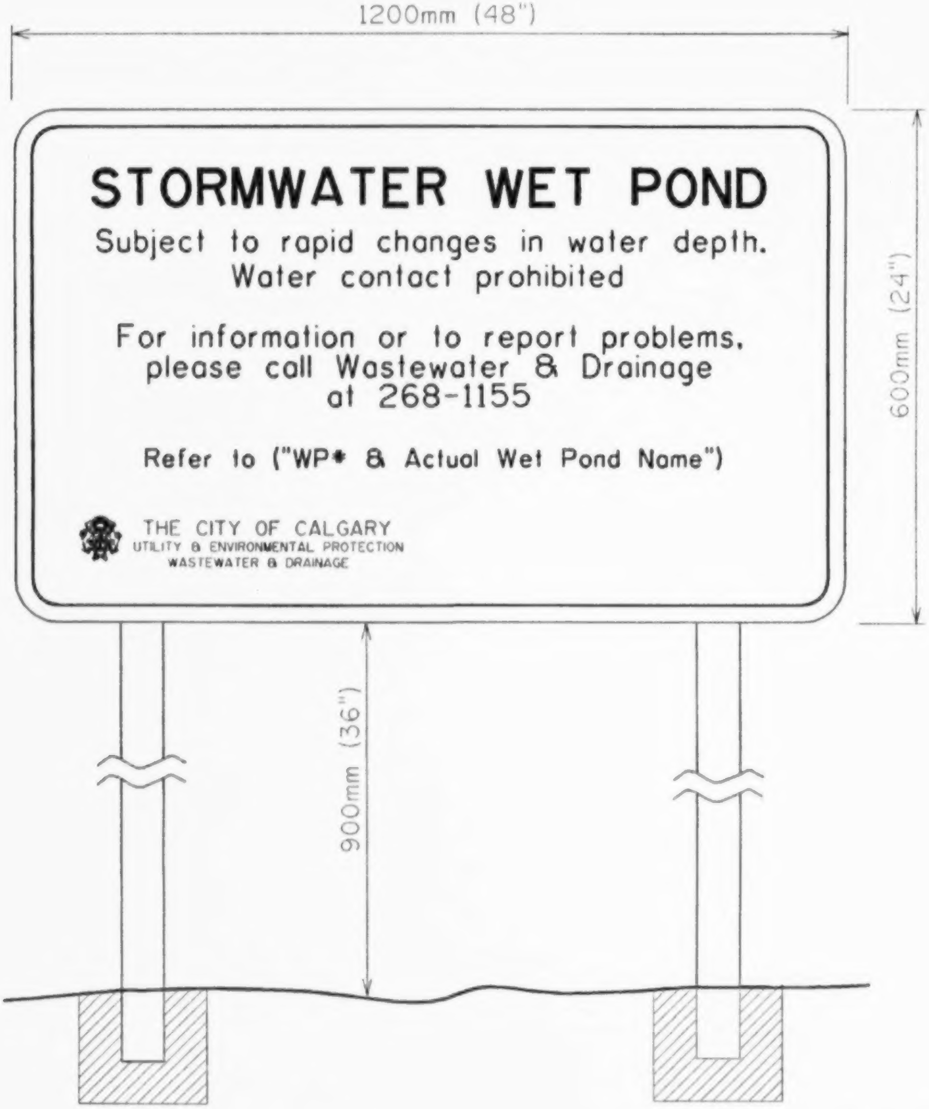
Drawn LC
Date [illegible]
Checked
Scale N.T.S.
Approved by

THE CITY OF CALGARY
ENGINEERING AND ENVIRONMENTAL SERVICES DEPARTMENT

STORMWATER STORAGE SITE
SIGN 500

Sheet 57D
File Number 452.1043.005

No.	Date	Revision	Appd


1200mm (48")
STORMWATER WET POND
Subject to rapid changes in water depth.
Water contact prohibited
For information or to report problems,
please call Wastewater & Drainage
at 268-1155
Refer to ("WP# & Actual Wet Pond Name")
THE CITY OF CALGARY
UTILITY & ENVIRONMENTAL PROTECTION
WASTEWATER & DRAINAGE
600mm (24")
900mm (36")

No.	Date	Revision	App'd

Drawn NB
Date 200/06/27
Scale NTS
Approved for
City Engineer

THE CITY OF CALGARY
UTILITY & ENVIRONMENTAL PROTECTION

WET POND
INFORMATION SIGN

Sheet

File Number

Appendix E Recommended Plant Species

The list provided is intended as a guide only. It is not an exhaustive list of the native plants available for use in restoration projects in the Calgary area. The list covers species in all habitats from wetlands through to dry prairie habitats. These species should be available commercially, but there are many more species native to wetlands. This list was developed by Park Development & Operations and will be revised as necessary. It is recommended that Park Development & Operations be contacted to determine if an updated list is available.

Native species used in any project must be native to the Calgary area and appropriate for the site conditions. This means, for example, that you would not plant white spruce on a south-facing slope, since this is an inappropriate site for this species, although it is native to Calgary.

Locally sourced materials should be used (stock should originate from within 1–200 km of the restoration site). The success of the project will depend greatly upon the selection of appropriate species to establish a native cover. Horticultural varieties developed from native species are not appropriate.

The intent of restoration, and to a limited extent, naturalization is a process which seeks to emulate the structure, function, diversity and dynamics of a particular ecosystem. This differs fundamentally from a landscaping project and as a result the species used, planting stock and methods often differ in restoration projects.

Qualified personnel should be retained to make the determination of suitable species for a given project. It is not enough to simply select species from this list; a detailed understanding of the site conditions, the ecology of the selected restoration species as well as a detailed project plan and set of objectives is required. An environmental specialist such as a botanist, plant ecologist or range ecologist who is familiar with wetlands and restoration ecology should be retained to select species and assist in planning the project.

General guidelines for restoration and naturalization in Alberta can be found in the following publication:

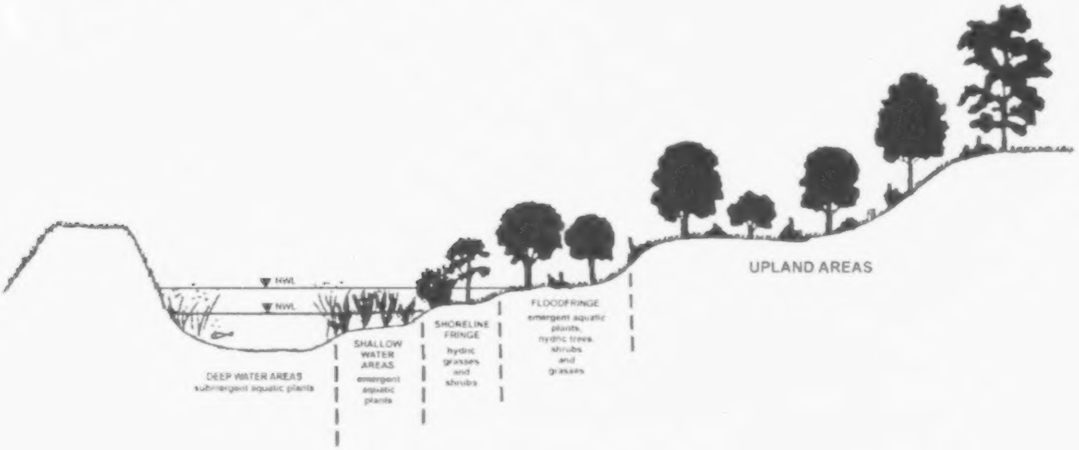
Native Plant Working Group. 1999. *Draft Native Plant Revegetation Guidelines for Alberta.* H. S. Gerling (ed.), Alberta Agriculture, Food and Rural Development. Edmonton, Alberta.

This document is available from:

Public Lands Division,
Alberta Agriculture, Food and Rural Development
Room 200, J.G.O'Donoghue Building
7000-113 St. Edmonton, Alberta T6H 5T6
It is also available on the Internet from < www.agric.gov.ab.ca/publiclands/nprg/index.html>

The Alberta Native Plant Council (Garneau P.O. Box 52099, Edmonton, AB T6G 2T5) publishes the *Native Plant Source List and Collection and Use Guidelines*, which provides a list of commercially available native plant materials. This document is available on the Internet at <www.anpc.ab.ca>.

Most of the species listed should be commercially available. Given that the intent of this list is for stormwater pond restoration/naturalization, they have been broadly classified in terms of moisture regime. This will serve as a general guide for selecting species. However, other considerations such as soil type, nutrient regime, aspect, and slope position may be of equal or greater importance.


HWL
NWL
DEEP WATER AREAS
submergent aquatic plants
SHALLOW WATER AREAS
emergent aquatic plants
SHORELINE FRINGE
hydric grasses and shrubs
FLOODFRINGE
emergent aquatic plants, hydric trees, shrubs and grasses
UPLAND AREAS

Moisture regime	Typical habitat
Aquatic	Floating-leaved and submergent plants. Generally must be in water throughout the growing season
Emergent	Rooted in the substrate, but with leaves and stems generally growing out of the water.
Hydric-mesic upland	Plants growing in saturated through to moist soils
Mesic-xeric upland	Plants growing in moist soils through to dry soils

Some species in the following list are potentially invasive; they should be used with some caution as they have the potential to significantly alter the specie composition of a site and may exclude or eliminate other species.

Latin name	Common name	Moisture Regime				Notes
		Aquatic	Emergent	Hydric-mesic upland	Mesic-xeric upland	
Grasses						
Agropyron riparium	steambank wheat grass			•	•	
Beckmannia syzigachne	slough grass		•	•		
Bouteloua gracilis	blue grama				•	
Calamagrostis canadensis	bluejoint grass		•	•		Potentially invasive
Calamovilfa longifolia	sand grass prairie sand reed				•	
Cinna latifolia	slender wood grass			•		
Danthonia caespitosa	California oat grass				•	
Danthonia parryi	Parry oat grass				•	
Deschampsia caespitosa	tufted hair grass			•		
Distichlis stricta	alkali grass		•	•		
Elymus canadensis	Canada wild rye			•	•	
Elymus cinereus (E. piperi)	giant wild rye				•	
Festuca campestris	foothills rough fescue				•	
Festuca halli	plains rough fescue				•	
Glyceria grandis	tall manna grass		•	•		
Helictotrichon hookeri	Hooker's oatgrass				•	
Hierochloe odorata	sweet grass			•	•	Potentially invasive
Muhlenbergia richardsonis	mat muhly		•	•		
Oryzopsis hymenoides	indian rice grass				•	
Phalaris arundinacea	reed canary grass		•	•		Potentially invasive
Poa canbyi	early bluegrass			•	•	
Poa juncifolia	alkali bluegrass		•			
Poa palustris	fowl bluegrass			•		
Poa sandbergii	Sandberg's bluegrass				•	
Puccinellia distans	slender salt-meadow grass			•		
Puccinellia nuttalliana	Nuttall's alkali grass			•		
Sagittaria cuneata	arrowhead		•			
Sanicula marilandica	snakeroot			•		
Schizachyrium scoparium	little bluestem				•	
Spartina gracilis	alkali cord grass		•	•		
Spartina pectinata	prairie cord grass		•	•		
Stipa comata	needle and thread, spear grass				•	
Stipa curtiseta	western porcupine grass				•	
Stipa richardsonii	richardson's needle grass				•	
Stipa spartea	porcupine grass				•	
Stipa viridula	green needle grass			•	•	
Sedges, rushes, and broad-leaved aquatics						
Alisma plantago-aquatica	broad-leafed water plantain		•			

Latin name	Common name	Moisture Regime				Notes
		Aquatic	Emergent	Hydric-mesic upland	Mesic-xeric upland	
Alisma triviale	western water plantain		•			
Carex aquatilis	water sedge		•	•		
Carex atherodes	awned sedge		•	•		
Carex rostrata	beaked sedge		•	•		
Ceratophyllum demersum	hornwort	•				
Eleocharis acicularis	least spike-rush	•				
Eleocharis palustris	creeping spike-rush	•				
Equisetum hyemale	horsetail rush	•	•			
Hippuris vulgaris	mare's-tail		•	•		
Juncus balticus	wire rush		•	•		
Juncus nodosus	knotted rush		•	•		
Juncus torreyi	Torrey's rush		•	•		
Lemna minor	duckweed	•				
Mentha arvensis	Canada mint			•		
Myriophyllum exalbescens		•				
Polygonum amphibium	water smartweed	•				
Ranunculus cymbalaria	creeping buttercup		•	•		
Scirpus acutus	hardstem bulrush		•			
Scirpus americanus	American bulrush		•			
Scirpus maritimus	alkali bulrush		•			
Scirpus microcarpus	small-fruited bulrush		•			
Scirpus validus	common great bulrush		•			
Triglochin maritima	arrow-grass	•	•			
Typha latifolia	cattail		•			Potentially invasive
Trees and shrubs						
Alnus crispa	green alder			•		
Amelanchier alnifolia	saskatoon				•	
Arctostaphylos uva-ursi	kinnikinnick, common bearberry				•	
Artemisia campestris	plains wormwood				•	
Artemisia cana	sagebrush				•	
Betula occidentalis	water birch, black birch		•	•		
Chrysothamnus nauseosus	rabbit-brush				•	
Clematis ligusticifolia	western clematis			•		
Clematis occidentalis	purple clematis			•		
Cornus stolonifera	red osier dogwood			•	•	
Crataegus rotundifolia					•	
Elaeagnus commutata	silver-berry; wolf willow				•	
Juniperus communis	common juniper				•	
Juniperus horizontalis	horizontal juniper				•	
Lonicera dioica	twining honeysuckle			•		

Latin name	Common name	Moisture Regime				Notes
		Aquatic	Emergent	Hydric-mesic upland	Mesic-xeric upland	
Philadelphus lewisii	mock orange				•	
Picea glauca	white spruce			•	•	
Populus tremuloides	trembling aspen			•	•	
Populus balsamifera	balsam poplar			•	•	
Potentilla fruticosa	shrubby cinquefoil				•	
Pseudotsuga menziesii	Douglas fir				•	
Ribes aureum	golden currant			•	•	
Ribes lacustre	bristly black currant			•	•	
Ribes oxyacanthoides	wild gooseberry				•	
Rosa acicularis	prickly rose			•	•	
Rosa arkansana	prairie rose			•	•	
Rosa woodsii	common wild rose			•	•	
Rubus idaeus	wild red raspberry			•	•	
Rubus pubescens	dewberry			•	•	
Salix amygdaloides	peach-leaved willow			•		
Salix bebbiana	beaked willow			•	•	
Salix discolor	pussywillow; diamond willow			•		
Salix exigua	sandbar willow			•		
Salix glauca	smooth willow			•		
Salix lutea	yellow willow			•	•	
Sambucus racemosa	elderberry			•		
Shepherdia argentea	silver/thorny buffaloberry			•	•	
Shepherdia canadensis	Canada buffaloberry				•	
Spiraea betulifolia	white meadowsweet			•		
Symphoricarpos albus	snowberry			•	•	
Symphoricarpos occidentalis	buckbrush/wolfberry			•	•	
Viburnum edule	low bush cranberry			•	•	
Viburnum opulus	high bush cranberry			•	•	
Forbs						
Achillea millefolium	yarrow				•	
Agoseris glauca	false dandelion				•	
Allium cernuum	nodding onion				•	
Allium schoenoprasum	wild chives				•	
Allium textile	prairie onion				•	
Anaphalis margaritacea	pearly everlasting				•	
Androsace septentrionalis	fairy candelabra				•	
Anemone canadensis					•	
Anemone cylindrica	long-fruited anemone				•	
Anemone multifida	cut-leaved anemone				•	
Anemone occidentalis					•	
Anemone patens	prairie crocus				•	

Latin name	Common name	Moisture Regime				Notes
		Aquatic	Emergent	Hydric-mesic upland	Mesic-xeric upland	
Antennaria rosea	rosy everlasting				•	
Aralia nudicaulis	wild sarsaparilla				•	
Arnica fulgens	shining arnica				•	
Artemisia frigida	pasture sagewort				•	
Artemisia ludoviciana	prairie sagewort				•	
Aster conspicuus	showy aster				•	
Aster ericoides	trusted white prairie aster				•	
Aster falcatus	creeping white prairie aster				•	
Aster laevis	smoothing aster				•	
Aster sibiricus	arctic aster				•	
Astragalus alpinus	alpine milk vetch				•	
Astragalus americanus	American milk vetch				•	
Astragalus bisulcatus	two-grooved milk vetch				•	
Astragalus canadensis	Canada milk vetch				•	
Astragalus crassicarpus	groundplum				•	
Astragalus drummondii	Drummond's milk vetch				•	
Astragalus gilviflorus	cushion milk vetch				•	
Astragalus missouriensis	Missouri milk vetch				•	
Astragalus pectinatus	narrow-leaved milk				•	
Astragalus striatus	ascending purple milk vetch				•	
Astragalus tenellus	slender-leaved milk vetch				•	
Atriplex nuttallii	Nuttall's atriplex, salt,sage		•	•		
Bidens cernua	nodding beggar-ticks		•	•		
Campanula rotundifolia	bluebell, harebell			•	•	
Castilleja lutescens	yellow indian paintbrush				•	
Castilleja miniata	red indian paintbrush				•	
Chenopodium capitatum	strawberry blite			•	•	
Chrysopsis villosa	hairy golden aster				•	
Cleome serrulata	bee plant				•	
Corydalis aurea	golden corydalis				•	
Delphinium glaucum	tall larkspur			•	•	
Disporum trachycarpum	fairy bells			•		
Dodecatheon conjugens	shooting star			•	•	
Dodecatheon pulchellum	shooting star			•	•	
Dryas drummondii	yellow dryad				•	
Epilobium angustifolium	fireweed; great willow-herb				•	
Epilobium ciliatum	northern willow-herb				•	
Erigeron caespitosus	tufted fleabane				•	
Erigeron compositus	compound fleabane				•	
Erigeron glabellus	smooth fleabane			•	•	
Erigeron philadelphicus	Philadelphia fleabane			•	•	

Latin name	Common name	Moisture Regime				Notes
		Aquatic	Emergent	Hydric-mesic upland	Mesic-xeric upland	
Erigeron speciosus	showy fleabane				•	
Eriogonum flavum	yellow umbrella-plant				•	
Eurotia lanata	winter fat				•	
Fragaria virginiana	wild strawberry			•	•	
Gaillardia aristata	gaillardia				•	
Galium boreale	northern bedstraw			•	•	
Gaura coccinea	scarlet butterfly weed				•	
Gentianella amarella	gentian				•	
Geranium richardsonii	wild white geranium				•	
Geranium viscosissimum	sticky purple geranium				•	
Geum aleppicum	yellow avens			•	•	
Geum macrophyllum	yellow avens			•	•	
Geum rivale	purple avens			•		
Geum triflorum	old man's whiskers/prairie smoke				•	
Glycyrrhiza lepidota	wild licorice				•	
Grindelia squarrosa	gumweed				•	
Gutierrezia sarothrae	broomweed				•	
Habenaria hyperborea	green orchid			•		
Haplopappus spinulosus	spiny iron plant				•	
Hedysarum boreale	northern hedysarum				•	
Hedysarum sulphurescens	yellow sweetvetch				•	
Helianthus annuus	common annual sunflower				•	
Helianthus laetiflorus var. *subrhomboideus*	rhombic-leaved sunflower				•	
Helianthus nuttallii	common tall sunflower				•	
Heracleum lanatum	cow parsnip			•		
Heuchera cylindrica	sticky alumroot				•	
Lathyrus ochroleucus	cream coloured vetchling			•		
Liatris punctata	dotted blazing star				•	
Lilium philadelphicum	western wood lily			•	•	
Linnaea borealis	twinflower				•	
Linum lewisii	wild flax				•	
Linum rigidum	yellow flax				•	
Lithospermum ruderale	woolly gromwell				•	
Lomatium dissectum	mountain wild parsley			•	•	
Lomatium macrocarpum	long fruited parsley			•	•	
Lupinus sericeus	flexile lupine				•	
Lygodesmia juncea	skeletonweed				•	
Lysimachia ciliata	fringed loosestrife			•		
Maianthemum canadense	wild lilly-of-the-valley			•		
Malvastrum coccineum	scarlet mallow				•	

Latin name	Common name	Moisture Regime				Notes
		Aquatic	Emergent	Hydric-mesic upland	Mesic-xeric upland	
Mitella nuda	bishop's cap			•		
Monarda fistulosa	wild bergamont			•		
Oenothera biennis	yellow evening primrose			•	•	
Orthilia secunda	one-sided wintergreen			•	•	
Orthocarpus luteus	owl's clover				•	
Oxytropis campestris	locoweed				•	
Oxytropis deflexa	reflexed locoweed				•	
Oxytropis monticola	late yellow locoweed				•	
Oxytropis sericea	early yellow locoweed				•	
Oxytropis splendens	showy locoweed				•	
Oxytropis viscida	viscid locoweed				•	
Parnassia palustris	grass of parnassia			•		
Penstemon confertus	yellow beardtongue				•	
Penstemon nitidus	smooth blue beardtongue				•	
Penstemon procerus	slender blue beardtongue				•	
Perideridia gairdneri	squaw root			•	•	
Petalostemon purpureus	purple prairie clover				•	
Petasites palmatus	palm-leaved coltsfoot				•	
Petasites sagittatus	coltsfoot			•		
Physaria didymocarpa	twin bladderpod				•	
Polygala senega	seneca snakeroot			•	•	
Potentilla anserina	silverweed		•	•		
Potentilla arguta	white cinquefoil			•	•	
Potentilla gracilis	graceful cinquefoil			•	•	
Potentilla hippiana	woolly cinquefoil				•	
Potentilla pensylvanica	prairie cinquefoil			•	•	
Primula incana	mealy primrose			•		
Psoralea esculenta	indian breadroot			•	•	
Pyrola asarifolia	common pink wintergreen			•		
Ranunculus glaberrimus	shining leaved buttercup			•	•	
Ranunculus pedatifidus var affinis	northern buttercup			•	•	
Ratibida columnifera	prairie cone-flower				•	
Rumex occidentalis	western dock			•		
Rumex venosus	wild begonia				•	
Sagittaria latifolia	broadleaf arrowhead		•			
Senecio canus	prairie groundsel				•	
Sisyrinchium montanum	blue-eyed grass				•	
Sisyrinchium sarmentosum	white blue-eyed grass				•	
Sium suave	water parsnip		•			
Smilacina racemosa	false solomon's seal			•	•	

Latin name	**Common name**	**Moisture Regime**				**Notes**
		Aquatic	**Emergent**	**Hydric-mesic upland**	**Mesic-xeric upland**	
Smilacina stellata	star-flowered solomon's seal			•	•	
Solidago canadensis	Canada goldenrod				•	
Solidago missouriensis	Missouri goldenrod			•	•	
Solidago mollis	velvety goldenrod				•	
Solidago rigida	stiff goldenrod				•	
Solidago spathulata	rocky mountain goldenrod				•	
Sphaeralcea coccinea	scarlet mallow				•	
Stachys palustris	hedge nettle			•		
Thalictrum dasycarpum	tall meadow rue			•	•	
Thalictrum venulosum	veiny meadow rue			•	•	
Thermopsis rhombifolia	golden bean				•	
Urtica dioica	stinging nettle		•	•		
Vicia americana	wild vetch			•	•	
Viola adunca	early blue violet			•	•	
Viola canadensis	Canada violet			•		
Viola nuttallii	yellow prairie violet				•	
Zigadenus elegans	white camas				•	
Zizia aptera	heart-leaved alexanders			•		

Appendix F Wetland Designs Comparison

Attributes of Four Stormwater Wetland Designs[16]

Attribute/ Sizing Criteria	Shallow Marsh	Pond-Wetland	ED Wetland	Pocket Wetland
Treatment Volume (V_t) Wetland:Watershed Ratio	Capture 90% of runoff volume from contributing watershed 0.02:1	Capture 90% of runoff volume from contributing watershed 0.01:1	Capture 90% of runoff volume from contributing watershed 0.01:1	Capture 90% of runoff volume from contributing watershed 0.01:1
Pollutant Removal Capability	Moderate, reliable removal of sediments and nutrients	Moderate to high, reliable removal of nutrients and sediment	Moderate, less reliable removal of nutrients	Moderate, can be subject to re-suspension and groundwater displacement
Land Consumption	High, shallow marsh storage consumes space	Moderate, as vertical pool substitutes for marsh storage	Moderate as vertical ED substitutes for marsh storage	Moderate, but can be shoehorned in site
Surface Area Allocation				
-% forebay	5	0	5	0
-% micropool	5	5	5	0
-% deep pool	5	40	0	5
-% lo marsh(15-45 cm)	40	25	40	50
-% hi marsh(0-15 cm)	40	25	40	40
-% semi-wet	5	5	10	5
Treatment Volume				
-% forebay	10	0	10	0
-% micropool	10	10	10	0
-% deep pool	10	60	--	20
-% lo marsh (15-45 cm)	45	20	20	55
-% hi marsh (0-15 cm)	25	10	10	25
-% semi-wet	0	0	50	0
Flow Path				
- min. L:W	1:1	1:1	1:1	N/A
- dry weather L:W	2:1	2:1	2:1	2:1
Water Balance	Base flow ≥ 1.4 (10^{-4}) cms/ha			**
Extended Detention (ED)	N/A	N/A	$ED_v = 50\% V_t$ ED rise < 1 m	N/A
Min. Drainage Area (ha)	10	10	4	0.4< area < 4
Forebay	required	no	required	optional
Outlet Micropool	required	required	required	optional
Outlet Type	Rev. slope pipe or broad crest weir	Rev. slope pipe or broad crest weir	Rev. slope pipe or broad crest weir	Broad crest weir
Cleanout Frequency (yrs)	2-5	10	2-5	10
Buffer Zone (m)	8-15	8-15	8-15	0-8
Outlet Micropool	mulch/transplant	mulch/transplant	mulch/transplant	mulch/transplant

---

[16] Shueler, Thomas et al, "*Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Mid-Atlantic Region*", 1992

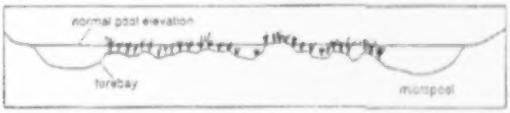
Pondscaping Emphasis	Wildlife habitat marsh topography buffer	Wildlife habitat hi marsh	ED zone stability pondscaping zones	Pondscaping optional
Native Plant Diversity	High, if complex microtopography is present	High, with sufficient wetland complexity and area	Moderate, fluctuating water levels impose physiological constraints	Low to moderate, due to small surface area and poor control of water levels
Wildlife Habitat Potential	High, with complexity and buffer	High, with buffer, attracts waterfowl	Moderate, with buffer	Low, due to small area and low diversity

** Typically sustained by excavation to water table.

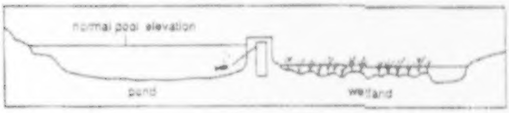
Deep Water - 0.3 – 1.8 m below normal pool (includes forebays, micropools, pools and channels)
Lo Marsh - 15 – 45 cm below normal pool
Hi Marsh - 0 – 15 cm below normal pool
Semi-wet - 0 – 0.6 m above normal pool (includes ED)

NOTE: The allocation targets are general guidelines and will vary according to design and site constraints.

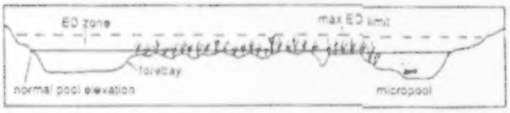
SHALLOW MARSH


normal pool elevation
forebay
micropool

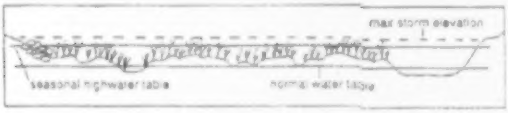
POND/WETLAND SYSTEM


normal pool elevation
pond
wetland

ED WETLAND


ED zone
max ED limit
forebay
normal pool elevation
micropool

POCKET WETLAND


max storm elevation
seasonal highwater table
normal water table

Wetland Cross Sections

Appendix G Source Control BMPs

Source Control BMPs for Household Activities

CONTAMINANT	SOURCES	BEST MANAGEMENT PRACTICES
Suspended solids	Exposed soils, organic and inorganic grit and debris left on urban surfaces	• Introduce and enforce litter control programs. • Control pet populations • Introduce and enforce dog litter bylaws. • Promptly remove or properly store household garbage and yard wastes. • Sweep pavement and roofs rather than washing. • Stabilize exposed soils and banks.
Oxygen-demanding substances	pet faeces, decaying household and yard wastes	• Properly dispose of or compost household and yard wastes. • Cover, clean and maintain trash can areas. • Clean up and properly dispose of pet wastes.
Toxic metals and organic compounds, oil and grease	Fluid leaks from vehicles, illicit dumping, household cleaners, paints, pesticides	• Repair fluid leaks in vehicles • Wash vehicles on the lawn rather than on paved surfaces connected to storm drains. • Recycle used oil. • Use alternative, less hazardous household products. • Properly handle, store, and dispose of hazardous household products. • Implement household hazardous waste collection. • Sweep pavement and roofs rather than washing. • Absorb spills using kitty litter. • Minimize pesticide use (use Integrated Pest Management).
Nutrients	Decaying vegetation and animal wastes, fertilizers, detergents, exposed soils	• Stabilize exposed soils with vegetation. • Collect and properly dispose of or compost yard wastes and pet faeces. • Do not dump or compost plant debris near receiving water bodies. • Apply fertilizer sparingly and at the right time. • Use low-phosphate detergents. • Wash vehicles on the lawn rather than on paved surfaces connected to storm drains.
Bacteria	Pet faeces, decaying household and yard wastes	• Collect and properly dispose of or compost yard wastes and pet faeces. • Cover, clean, and maintain trash can areas.
All	Illicit dumping, poor waste handling and disposal practices, erosion	• Comprehensive public education. • Erosion control.

Source Control BMPs for Commercial and Industrial Activities

(Adapted from City of Bellevue, 1991)

CONTAMINANT	SOURCES	BEST MANAGEMENT PRACTICES
Suspended solids	Exposed soils, organic and inorganic debris left on urban surfaces	• Cover exposed soils and debris stockpiles. • Clean and maintain business sites. • Sweep pavement and roofs rather than pressure washing. • Stabilize eroding banks and unpaved areas. • Preserve stream corridors.
Oxygen-demanding substances	Decaying vegetation, animal wastes, food wastes, and chemical wastes	• Fix, cover, or berm leaky dumpsters. • Promptly clean up outdoor spills. • Properly recycle, compost, and dispose of wastes. • Sweep pavement and roofs rather than pressure washing.
Toxic metals and organic compounds, oil and grease	Vehicle repair, paints, fuel and waste oil, antifreeze, brake fluid, battery acid, solvents, cleaners, sealers, pesticides, leaky dumpsters, cleaning vents, oil leaks in vehicles and equipment, steam cleaning, equipment maintenance	• Maintain a clean and organized work area. • Do not sand or grind outside, unless on a tarp. • Clean up metal dust and shavings. • Cover containers and materials. • Cover or berm oily wastes and dumpsters. • Properly recycle and dispose of used and excess materials. • Handle toxic materials carefully. • Use care when filling and draining containers. • Plan for and control spills. • Cover and properly drain fueling and loading areas. • Wash vehicles and parts in designated and properly drained areas. • Minimize pesticide use (use Integrated Pest Management). • Repair oil leaks on vehicles and equipment. • Recycle oil where possible. • Properly dispose of non-recyclable wastes. • Install and maintain oil-water separators.
Nutrients	Decaying vegetation and animal wastes, fertilizers, detergents, exposed soils	• Control erosion. • Plant cover vegetation on exposed soils. • Carefully choose plants and landscape features. • Properly dispose of or compost organic wastes. • Do not dump or compost plant debris near receiving water bodies. • Apply fertilizer sparingly and at the right time. • Wash only in designated and properly drained areas. • Use low-phosphate detergents.
All	Illicit dumping, improper connections to storm sewers, poor waste handling and disposal practices, erosion	• Comprehensive education and technical support. • Inspection, follow-up and enforcement of BMPs. • Eliminate improper and illegal connections to storm sewers. • Control erosion.

Source Control BMPs for Construction Activities
(Adapted from City of Bellevue, 1990)

CONTAMINANT	SOURCES	BEST MANAGEMENT PRACTICES
Sediment, nutrients, particulate-associated metals and organics, oil and grease	Clearing or grading land, construction near a stream	• Plan the development to fit the topography, soils, drainage patterns and natural vegetation of the site. • Avoid unnecessary modification of the site to suit a particular development design. • Preserve vegetation and cover soils. • Stage work to minimize the disturbed area and duration of exposure. • Establish cover vegetation immediately after final grading. • Control runoff during construction. • Prevent off-site water from running over disturbed areas. • Keep runoff velocities low. • Stabilize disturbed areas with temporary covers or mechanical-structural methods. • Install sediment controls. • Clean catch basins. • Fix any oil leaks in equipment. • Preserve the stream corridor and take steps to enhance it.
Toxic and acidic pollutants, sediments	Handling fresh concrete or other cement-related mortars	• Never wash fresh concrete mortar into a storm drain or stream – use designated wash-out areas. • When building concrete aggregate driveways, wash fines to the side, to straw bales, or to a sediment basin.
Toxic metals and organics, oil and grease	Painting, sanding, plastering, applying drywall paper or tile, any activities using paints, batteries, solvents, or adhesives	• Keep residue such as paint chips from entering storm drains (e.g. catch chips on a tarp). • Keep paints, solvents, chemicals, waste containers, and soiled rags covered from the rain. • Prepare for and clean up spills. • Minimize wastes and properly dispose of or recycle all wastes. • Fix any oil leaks in equipment.
All	General contracting and construction site management, training employees	• Include training about water quality BMPs. • Ensure all workers know proper BMP procedures. • Ensure all applicable BMPs are followed.

Appendix H Minimum Requirements for Erosion & Sediment Control Reports

MINIMUM REQUIREMENTS FOR EROSION AND SEDIMENT CONTROL REPORTS

Reporting Requirements	Mapping Requirements
1. Location and Site Characteristics	
• Describe the location of the proposed development. Include legal description of the site and a reference to adjacent properties and landmarks. • Describe existing land use: - general topography (slopes and slope lengths within the site) - vegetation - soil types (particle sizes, erodibility) - extent and nature of development - drainage patterns - critical areas within the proposed development site that have potential for serious erosion or sediment problems • Identify neighbouring areas such as streams, lakes, residential and commercial areas, reserves, parks and roads that might be affected by the land disturbance.	• Provide location plan showing: - legal land description; and - adjacent properties (streams, lakes, residential and commercial areas, reserves, parks and roadways). • Provide contour plans of existing area and tabulation of slopes and slope lengths. • Indicate the location of trees, shrubs, grass and unique vegetation. • Show the different soil types within the proposed development. • Show the kinds of development on adjacent properties. • Topographic maps should have a sufficient contour interval to determine drainage patterns. Show the drainage divides and flow directions for each drainage area. • Show critical areas within or near the development.
2. Proposed Development	
• Provide a general description of the proposed development with a brief description of the nature and purpose of the land disturbing activity. • Indicate the area and amount of grading proposed for each stage of grading. • Describe the permanent stormwater management system and the use of their facilities during the construction period pertaining to sediment control.	• Show the limits of clearing and grading for each phase of the development. Each boundary line should be identified as to the timing and duration of disturbances. • Show the drainage divides and flow directions for each drainage area after development and show the changes resulting from grading. Include a contour plan of the finished grades at an appropriate scale (1:2000). • Indicate the location and sizes of permanent storm drain inlets, pipes, outlets and other permanent drainage facilities such as swales, waterways, etc.
3. Erosion & Sediment Controls	
• Determine runoff quantities. • Provide a description of the methods that will be used to control erosion and sediment transport on the site. Provide detailed design information and calculations as required. Stabilization of soils should be the first line of defence. • Identify **temporary** and **permanent** control methods. • Indicate good housekeeping practices. • Show the location, height, and volume of stockpiles. - Indicate erosion control measures used to control sediment runoff from the stockpiles. • Indicate the types and scheduling of individual erosion control measures, including interim or short-term measures (less than 45 days duration). • Clearly indicate the measures to control sediment export off the development site. • Describe how the site will be stabilized after construction is completed.	• Indicate the locations, types and sizes/dimensions of the proposed temporary and permanent erosion and sediment control measures including ponds/sedimentation basins and inlet protection. • Show types, locations and dimensions of erosion and sediment control measures on a plan map, for each phase of construction. • Provide details of ESC measures as required. • The location and size of each stockpile should be indicated and annotated with the volume and height. • Show the locations and dimensions of silt fences, sedimentation traps/ponds, berms, etc. • Clearly indicate the measures which will be maintained following construction. • Indicate if bedrock will be encountered during grading.
4. Inspection & Maintenance	
• Provide a schedule of regular inspections and expected repairs of erosion and sediment control devices. • Record changes made to ESC Plan due to changing conditions.	• Update ESC Plan with revised erosion and sediment control measures.

Appendix I Maintenance and Response Procedures for Stormwater Ponds (Wastewater & Drainage)

CITY OF CALGARY-WASTEWATER & DRAINAGE
MAINTENANCE AND RESPONSE PROCEDURES
STORMWATER PONDS

1.0 MAINTENANCE PROCEDURES

1.1 Preventive Maintenance by Systems Maintenance Group

The Systems Maintenance group is responsible for preventive maintenance to ensure proper operation of stormwater ponds including clearing and disposal of debris and garbage from the pond area and from the structures within the pond area. **Ponds located on school sites shall have highest priority.**

The preventive maintenance is to be undertaken on all stormwater ponds at spring thaw and on the affected storm pond after each significant rainstorm. A significant rainstorm is generally one that will activate the first alarm in a monitored pond.

1.1.1 All catchbasins, inlet/outlet grates, trash racks and the orifice in the control structure should be checked and cleaned.

1.1.2 All garbage and debris should be removed from the pond area.

1.1.3 Damage to the sod or pond area should be repaired.

1.1.4 Ensure that all gratings and manhole lids, both upstream and downstream of the stormwater pond, are in place. Gratings and lids that are subject to displacement should be secured as a safety measure.

1.1.5 Where available, the sluice gate or gate valve in the control structure may be used to drain down the storm pond if it is established that the downstream storm sewer has capacity. The sluice gate or gate valve must be completely closed after the pond has been drained.

1.1.6 Heavy equipment is not allowed within the pond area immediately after the drain down to avoid damage to sod and underground pipe systems. In most cases, a 3m path is provided for access to the control structure.

1.1.7 Where there is a weeping tile or subdrainage system, blockages must be cleared through the cleanouts provided.

1.1.8 Before leaving the site, ensure that all gratings and structures are secured, and the sluice gate or gate valve is completely closed.

1.2 Maintenance of Electrical and Alarm Systems

The Bonnybrook Treatment Plant (Electrical Branch) is responsible for preventive maintenance on the electrical and alarm systems in the stormwater ponds. Contact Doug Neilands at 268-3876 or the appropriate replacement.

The preventive maintenance on the electrical system is undertaken at all stormwater ponds at spring thaw and on the affected storm pond after each significant rainstorm (if required). A significant rainstorm is generally one that will activate the first alarm in a monitored pond.

Alarm systems in the monitored ponds are called up daily to ensure that the systems are operational. This check is printed out daily.

1.2.1 The electrical panel box that also houses the alarmed system in monitored ponds should be opened and checked for water infiltration. The box should be dry to prevent electrical hazards and to ensure proper operation of the electrical components.

1.2.2 All breakers in the electrical panel box should be checked and tripped breakers returned to the "ON" position.

1.2.3 Desiccant tubes that are applicable in some ponds, are located within the electrical panel boxes to control moisture. The desiccant should be blue in colour. When the desiccant is pink in colour, it should be removed, dried and replaced, or disposed of and replaced altogether.

1.2.4 All alarmed ponds have sonic sensors installed in the control structure. LWL and HWL alarms should be checked on an annual basis, at the beginning of the rain season. The intrusion alarm should also be checked.

1.2.5 Before leaving the site, ensure that all lids, gratings, and electrical panels are secured.

1.2.6 The "CTU" (central terminal unit) is called up daily to ensure that the alarms are being received at the Engineering Emergency Communication Centre (101) at Manchester.

Monitored ponds are equipped with a sonic sensor in the control structure and an intrusion alarm in the electrical cabinet. The following notes are applicable:

NOTE:
This cabinet contains an intrusion alarm. An open door will activate the alarm at the Engineering Emergency Communication Centre 101 at Manchester! Immediately turn the by-pass switch to deactivate the alarm. The alarm will be deactivated by the amount of time on the switch.

NOTE:
The control structure contains a sonic sensor that activates the low water level (LWL) and high water level (HWL) alarms at the Engineering Emergency Communication Centre 101 (E.E.C.C.) at Manchester.

If work is being done inside the structure a false alarm may be activated. Please notify the dispatch operator at the E.E.C.C. at Manchester 268-1155 for any impending work.

2.0 RESPONSE PROCEDURES

2.1 Response by Systems Maintenance Group

The Systems Maintenance group will respond to surcharging and other unacceptable conditions at stormwater ponds. Secure the affected ponds, monitor the water level at the pond area, and provide proper actions to relieve the situation as expeditiously as possible. **Ponds located on school sites shall have the highest priority.**

The stormwater pond will be secured by disallowing public access to the site. Dry ponds are secured when runoff is present in the pond area or when the first alarm is activated in the monitored dry ponds.

2.1.1 When a significant rainstorm is forecasted or during a rainstorm, the Duty Supervisor with Systems Maintenance will initiate steps to monitor the progress of the rainstorm, and when necessary, to check water levels at the affected stormwater ponds.

2.1.2 All complaints or reported emergencies due to surcharging or other unacceptable conditions at the stormwater ponds, are directed to the Duty Supervisor.

2.1.3 With respect to monitored dry ponds, the Engineering Emergency Communication Centre 101 at Manchester will advise the Duty Supervisor of the activation of alarms in the monitored ponds. The first alarm will indicate entry of storm runoff into the dry pond and the second alarm will indicate a water level at the maximum water level at the pond. When it is reported that water is in the monitored dry pond, but the alarm is not activated, the Duty Supervisor must inform the Engineering Emergency Communication Centre at Manchester so that the problem can be addressed.

2.1.4 All respondent crews from Systems Maintenance will be given a site map of each of the affected stormwater ponds from the map book on stormwater ponds.

2.1.5 Respondent crews from Systems Maintenance will provide proper actions to relieve the surcharging or other unacceptable conditions in the affected ponds. These actions may include clearing of debris at the catchbasins, outlet pipes, grates at inlet/outlet structures, control structures, etc. but only where it is safe to do so. Pumping or release of the sluice gate to drain the pond may only be allowed when it is safe to do so.

2.1.6 Personnel from Systems Maintenance will remain full-time on site to secure the affected ponds by disallowing public access to the pond area. The water level in the pond area will be timed and monitored in increments or reduction of 0.5 m. Dry ponds are to be secured until the pond area is fully discharged.

2.1.7 The Duty Supervisor will endeavour to establish the duration and severity of the rainstorm to make the necessary arrangements to secure the affected storm ponds after normal business hours, or when crews from Systems Maintenance are unavailable to provide this service due to the volume of emergency response.

2.1.8 Wastewater & Drainage will undertake all preventive maintenance on the affected storm ponds when the water level has receded or upon full discharge of the dry ponds.

2.2 Private Security Company

When the duration and severity of the rainstorm makes it necessary to secure the stormwater ponds after normal business hours, or when Systems Maintenance is unable to provide the required manpower during or after normal business hours, the Duty Supervisor will make the arrangements with the private security company that is currently under contract with The City of Calgary, Corps of Commissionaires (hereinafter called the Contractor), to provide the personnel to undertake the work.

2.2.1 The Duty Supervisor will provide instructions directly to Jim Reekie (or appropriate alternate) with the Contractor at 244-4664 between 0800 and 1600 hours Monday to Friday. Outside of normal business hours (between 1600 and 0800 hours Monday to Friday, and at all hours (24) Saturday, Sunday and Holidays), Mr. Reekie can be reached by leaving a short message and telephone number with the Contractor's Duty Dispatcher at 244-4664. Mr. Reekie will return the call within 15 minutes.

2.2.2 Upon instructing Mr. Reekie, the Duty Supervisor will provide 2-way radios and appropriate site maps for each of the affected storm ponds, which must be picked up by the Contractor at Manchester Central Dispatch. An additional radio will be given to the Duty Officer at Manchester Central Dispatch for required communications with each assigned security officer at the affected storm ponds.

2.2.3 One full-time Security Officer is required at each affected storm pond or system. The Security Officer will pick up the site map of the assigned pond and a portable 2-way radio from the Duty Supervisor or from the Duty Officer at Manchester Central Dispatch. Schools are to have the highest priority.

2.2.4 The Security Officer will secure the assigned storm pond by disallowing public access to the site, and will maintain a timed log on increments or reduction of 0.5 m of the water level in the pond.

2.2.5 The Security Officer at each assigned pond will use the portable 2-way radio to check in every hour on the hour to the Duty Officer at Manchester Central Dispatch and to report any problem or request for assistance.

2.2.6 The Contractor's Security Supervisor will provide random checks on the security officers at the affected storm ponds. The Security Supervisor will confirm each random check to the Duty Officer at Manchester by the portable 2-way radio provided.

2.2.7 In the event of a problem or emergency, or when the water level at the stormwater pond reaches the high water level, the Security Officer will contact the Duty Officer at Manchester Central Dispatch by the portable 2-way radio. The latter will then contact the Duty Supervisor with Systems Maintenance. In addition, the Engineering Emergency Communication Centre 101 at Manchester will advise the Duty Supervisor of the tripping of the second alarm that will indicate the water level is at the high water level.

2.2.8 Both the Security Officer and the Duty Officer at Manchester will each maintain a timed log on all radio calls to and from one another, random checks by the Contractor's Security Supervisor, and any other radio calls in the duration of the security officer's shift at the assigned storm pond.

2.2.9 After the completion of the work shift, the timed logs by the security officers will be delivered to the Duty Supervisor at the Office of Systems Maintenance the following morning.

2.2.10 On-site services by the Contractor will end when it is established by the Duty Supervisor that the water level has receded or when the dry ponds are fully discharged.

2.2.11 Wastewater & Drainage will undertake all preventive maintenance on the affected ponds when the water level has receded or upon full discharge of the dry ponds.

Appendix J Stormwater Pond Check Sheets

CITY OF CALGARY-WASTEWATER & DRAINAGE STORMWATER POND INSPECTION REQUIREMENTS

The following is a list of items which should be checked before issuance of Wastewater & Drainage C.C.C. and F.A.C. All dry ponds shall comply with the requirements outlined in the City of Calgary's "Stormwater Management & Design Manual" (2000)

C.C.C. Inspection

1. Grading

The consultant must submit final as-built cross sections and contours of the entire pond. They should be plotted at the same stations and scale as the original design cross sections. Surveys from Parks & Recreation may be submitted. Items to be checked include:

Dry Pond

- **Side slopes** – The maximum side slope shall not exceed 5H:1V from pond bottom to HWL (high water level), including the freeboard. Above the inundated area, side slopes no greater than of 4H:1V are permitted for inward facing slopes and 3H:1V for outward facing slopes.
- **Bottom slopes** – The pond bottom shall have a minimum slope of 1.5%. A 2% slope is preferred.
- Bottom grading must provide positive drainage towards the catchbasins and inlet/outlet structure(s). There must be no areas of standing water. Wet soggy areas could also be a sign of irrigation system leaks.

Wet Pond

- **Side slopes & bottom slopes** – below NWL a 2 m wide 3H:1V side slope is required with the remainder being 5H:1V to 7H:1V. Between NWL and HWL, the maximum side slope should be 5H:1V. Above HWL, slopes of 4 to 5H:1V are permitted. Benches and other alterations are permitted as approved by WWD.

Wetlands

- **Side slopes** – grading below NWL should not exceed 10H:1V. Between NWL and HWL, grading should not exceed 5H:1V. Grading above HWL should be 4H:1V to 5H:1V maximum; outward facing slopes should not exceed 3H:1V. Alternating sections of 7H:1V can be used for terraced grading. Benches are permitted as approved by WWD.
- **Bottom slopes** – A bottom slope of 0.5 to 1.0% is recommended.

General

- **Design volume** – As-built volumes must be supplied. Any discrepancies between design and as-built volumes should be highlighted for comparison purposes.
- Ensure there are no signs of erosion throughout the pond. The inlet/outlet structure and catchbasins are the most susceptible to erosion.
- Ensure that the overland escape route/emergency spillway has been constructed as per the construction drawing(s). It is important that the spillway be in the proper location and at the proper elevation.
- Sediment forebays must be properly constructed.

2. Inlet/Outlet Structure

Inspect inlet/outlet structure(s) for design as shown on the construction drawing(s).

- Bottom of structure is to be benched so there is no standing water for dry ponds.
- Invert of grating(s) to be checked. Gratings are usually installed at specific elevations to allow stormwater flows into/out of the pond.
- Invert of incoming/outgoing pipe to be checked.
- Inlet pipe diameter to be ≥ 450mm (Dry Ponds Only)

- Grating(s) should be bolted down or secured for safety measures.
- Ensure there are no signs of erosion around the structure. Usually some type of erosion control protection is in place around the structure (ie. mats).
- Ensure there is little or no build-up of silt or debris.
- Ensure there is no damage to structure(s). This includes a check for cracking, honeycombing and spalling.

3. Catchbasins/Manholes (Dry Ponds Only)

Inspect all pond catchbasins and manholes for design as shown on the construction drawing(s).

- All rim and invert elevations must be checked.
- All catchbasin gratings should be bolted down or secured for safety reasons. Ensure proper grating has been used.
- Bottom of all manholes to be benched so there is no standing water.
- Ensure there are no signs of erosion around the catchbasins.
- Ensure there is little or no build-up of silt or debris.
- Ensure there is no damage to any of the catchbasins or manholes. This includes a check for cracking, honeycombing and spalling.

4. Control Structure

Inspect the control structure for design as shown on the construction drawing(s). For wet ponds & wetlands, inspection must be done prior to water being introduced into pond.

- Bottom of structure is to be benched towards the orifice. For dry ponds, there should be no standing water in the structure.
- All rim and invert elevations must be checked.
- Ensure there is little or no build-up of silt or debris.
- Ensure there is no damage to structure. This includes a check for cracking, honeycombing and spalling.

• **Gate valve**	- Ensure gate valve (if applicable) works properly. The gate must be easily engaged. - Valve face must seal properly and not leak. - Service provider to ensure automatic control gate system (if required) is set up and working properly.
• **Trash rack**	- Where required, the trash rack must be removable and easily cleaned. - The trash rack must be free of debris.
• **Weir wall**	- Check elevation of the top of the weir wall. The size of the opening must also be verified.
• **Orifice**	- The centerline or invert elevation of the orifice must be checked. It is important that this elevation be as close to design value as possible. - Dimensions of the orifice must be verified. - Ensure orifice plate fits snugly to the structure wall to minimize leakage around the plate.

5. Storm Pipe System

Inspect the storm pipe system for design as shown on the construction drawing(s).

- All invert elevations must be checked. For dry ponds, the piping within the pond bottom is usually low slope so it is important that elevations are close to design value.
- Upstream storm pipe under pressure (ie. below 1:100 year hydraulic grade line elevation) should be installed with rubber gaskets. Ensure drawings are properly labelled.
- Ensure that storm manholes designed with bolt-down covers have been properly installed.
- Pipes must be free of silt & debris.

6. **Subdrainage System (Dry Ponds Only)**
   Inspect the subdrainage system for design as shown on the construction drawing(s).
   - Invert elevations must be checked. It is important that elevations are close to design value.
   - Ensure cleanouts have been installed as indicated. Cleanout tops should be flush with ground surface.
   - Ensure drainage blankets have been installed as per design.
   - Weeping tile/subdrainage system should connect downstream of the control structure. If weeping tile connects to the internal catchbasins or the upstream side of the control structure, some type of backwater valve (ie. Red Valve) should be incorporated to prevent surcharging. Ensure these valves have been installed at the location(s) specified in the construction drawing(s).
   - System must be free of silt & debris.

7. **Sanitary Pipe System**
   Inspect the sanitary pipe system for design as shown on the construction drawing(s).
   - No sanitary sewer manholes are permitted within the pond area.

8. **Monitoring System**
   Inspect the monitoring system for design as shown on the construction drawing(s).
   - Ensure all level/alarm sensors are easily and safely accessible for Maintenance personnel.
   - Ensure all sensors have been installed at the proper elevations.
   - The approved service provider is responsible for checking the following:
     - Alarm conditions must be tested to ensure they ring through to the annunciator system EECC at Manchester. This requires that the alarm sensors be programmed to alarm at specified elevations. These elevations should correspond to pond bottom (LWL) and high water level (HWL) for dry ponds. For wet ponds and wetlands, the low level alarm should be set at NWL+0.1 m. A calibration certificate is required. The service provider must also supply a schematic of the inside of the structure (alarms).
   - Ensure that the doors on the electrical control box close/seal properly.
   - Ensure that the electrical control box is in good condition and does not show signs of rusting or damage.
   - Landscaping should slope away from electrical control box.
   - All conduit into the electrical control structure should be sealed to prevent infiltration of water and/or humidity.
   - Ensure all electrical equipment (i.e. fans, heater) works properly and has been properly installed.
   - The electrical control box should be locked with the Wastewater & Drainage "construction" lock. Locks are available from the Contracts & Construction Engineer (WWD).
   - The Stormwater Engineer (WWD) is responsible for checking the datalogger:
     - Datalogger must be recording and alarming properly. Phone number(s) must be supplied.

9. **Signs**
   - Approved signs must be placed at entrances to the pond. There must not be any damage to signs.

10. Miscellaneous

- **Ramp** – A 3.0 m wide (minimum) gravelled or paved access (or approved equivalent) from the adjacent street or lane is to be provided for emergency and maintenance vehicle access. As well, a pathway or gravelled road must extend to the control structure for maintenance purposes if possible.
- **Pathway** – The pathway must show no signs of cracking or heaving.
- All concrete structures should be checked for signs of cracking, honeycombing and spalling.
- The consultant is responsible for submitting all final as-built construction drawings in mylar material after a set of print drawings has been checked and approved.

11. Landscaping and Irrigation

All landscaping and irrigation is to be inspected by Park Development & Operations and must comply with the Landscape Construction Standard Specification and landscaping/vegetation approved on the construction drawings. It should be noted that ponds require C.C.C. and F.A.C. approval from **both** s and Wastewater & Drainage. All vegetation and landscaping must be healthy.

F.A.C. Inspection

Items 1 through 11 listed above should be rechecked as required (see check sheets). In addition, the following items should be checked:

12. Maintenance Requirements

All maintenance requirements must be carried out as per the "Stormwater Management & Design Manual".

The Final Acceptance Certificate (F.A.C.) maintenance period for the pond construction will be 3 years unless specified otherwise. Wetlands require 5 years maintenance period. For wet ponds, 3 years of maintenance is required from the time the last staging of construction is completed. Automatic control gate systems require 5 years maintenance period. For loaming, seeding and landscaping, the F.A.C. maintenance period will be 3 years from the time of seeding or tree planting, whichever occurs last.

13. Accounting Requirements

A copy of the F.A.C. must be submitted to accounting. At the time the FAC is approved, the Stormwater Engineer must make arrangements with accounting to have the telephone & utility accounts changed over to WWD.

DRY POND INSPECTION CHECK SHEET (July 2000)

Subdivision/Phase: ______________________ C.C.C. Issue Date: __________
Developer/Consultant: ______________________ F.A.C. Issue Date: __________

Item	Description	C.C.C.				F.A.C.			
		Acc.	N/A	Init	Date	Acc.	N/A	Init	Date
1.	**Grading.** · as-built cross sections of final grade submitted $^{(1,\text{N/A})}$						✓		
	· side slopes - 5H:1V between btm & HWL $^{(1,\text{ N/A})}$ - 4H:1V above HWL (inward facing) - 3H:1V above HWL (outward facing)						✓		
	· bottom slopes (1.5% min., 2.0% preferred) $^{(1,\text{ N/A})}$						✓		
	· design volume (final grade) $^{(1,\text{N/A})}$						✓		
	· no signs of erosion throughout the pond $^{(2,2)}$								
	· dry ponds - positive drainage towards catchbasins and inlet/outlet structure. No areas of standing water $^{(2,\text{N/A})}$						✓		
	· overland escape route/spillway as per construction drawing. Spillway in proper location at proper elevation $^{(1/2,\text{N/A})}$						✓		
	· sediment forebay(s) properly constructed $^{(1/2,\text{ N/A})}$						✓		
2.	**Inlet/Outlet Structure.** · bottom is benched so there is no standing water $^{(2,2)}$								
	· invert of grating(s) $^{(1/2,\text{ N/A})}$						✓		
	· invert of incoming/outgoing pipe $^{(1/2,\text{ N/A})}$						✓		
	· inlet pipe diameter $\geq$ 450 mm $^{(1/2,\text{ N/A})}$						✓		
	· gratings bolted down or secured $^{(2,2)}$								
	· no signs of erosion $^{(2,2)}$								
	· little or no buildup of silt or debris $^{(2,2)}$								
	· no damage to structure (cracking, honeycombing, spalling) $^{(2,2)}$								
3.	**Catchbasins/Manholes.** · rim and invert elevations $^{(1/2,\text{ N/A})}$						✓		
	· CB gratings bolted down or secured $^{(2,2)}$								
	· proper CB grating used $^{(2,\text{ N/A})}$						✓		
	· all manholes and catchbasins benched so there is no standing water $^{(2,\ 2)}$								
	· no signs of erosion $^{(2,2)}$								
	· little or no build-up of silt or debris $^{(2,2)}$								
	· no damage to CB's or MH's (cracking, honeycombing, spalling) $^{(2,2)}$								
4.	**Control Structure.** · bottom of structure benched towards orifice. No standing water $^{(2,\text{ N/A})}$						✓		
	· rim and invert elevations $^{(1,\text{ N/A})}$						✓		
	· little or no build-up of silt or debris $^{(2,2)}$								
	· no damage to structure (cracking, honeycombing, spalling) $^{(2,\ 2)}$								
	· **gate valve** - valve works properly (easily engaged) $^{(2,\ 2)}$								
	- valve face seals properly $^{(2,\ 2)}$								

Item	Description	C.C.C.				F.A.C.			
		Acc.	N/A	Init	Date	Acc.	N/A	Init	Date
	- automatic control gate(s) setup and working properly where applicable (SP, SP)								
	· **trash rack** - trash rack removable and easily cleaned (2, 2)								
	- trash rack free of debris (2, 2)								
	· **weir wall** - elevation of top of weir wall (1/2, N/A)						✓		
	- size of opening (1/2, N/A)						✓		
	· **orifice** - centerline or invert elevation (1, N/A)						✓		
	- dimensions of orifice (slot size, diameter) (1/2, N/A)						✓		
	- orifice plate fits snugly to wall to minimize leakage around the plate (2, 2)								
5.	**Storm Pipe System.** · invert elevations (1/2, N/A)						✓		
	· upstream piping fitted with rubber gasket (1/2, N/A)						✓		
	· storm manholes designed with bolt-down covers properly installed (2, N/A)						✓		
	· free of silt and debris (2, 2)								
6.	**Subdrainage System.** · invert elevations (1/2, N/A)						✓		
	· cleanouts installed as indicated. Tops flush with ground surface (2, 2)								
	· drainage blankets installed as per design (2, N/A)						✓		
	· weeping tile/subdrainage connected downstream of control structure. Backwater valves (ie. Red Valve) installed as specified (2, N/A)						✓		
	· free of silt and debris (2, 2)								
7.	**Sanitary Pipe System.** · No sanitary sewer manholes are permitted within the pond (2, N/A)						✓		
8.	**Monitoring System.** · all level/alarm sensors are easily and safely accessible (3, 3)								
	· all sensors/alarms installed at proper elevations (1/3, 1/3)								
	· approved service provider must ensure: – alarm conditions ring through to E.E.C.C. at Manchester. Requires alarm sensors programmed to alarm at specified elevations. A calibration certificate is required and a schematic of the inside of the structure from service provider (1/SP, 1/SP)								
	· doors on electrical control box close/seal properly (3, 3)								
	· electrical control box in good condition. No signs of rusting or damage (3, 3)								
	· landscaping slopes away from electrical control box (2/3, 2/3)								
	· all conduit into electrical control box sealed to prevent infiltration of water and/or humidity (3, 3)								
	· all electrical equipment (fans, heater) works properly and has been properly installed (3, 3)								
	· electrical control box locked with Wastewater & Drainage "construction" lock (2/3, 2/3)								

Item	Description	C.C.C.				F.A.C.			
		Acc.	N/A	Init	Date	Acc.	N/A	Init	Date
	· Stormwater Engineer (WWD) to check datalogger: · datalogger recording properly. Phone number(s) supplied (1, 1)								
9.	**Signs.** · approved signs placed at entrances to ponds. No damage to signs (2, 2)								
10.	**Miscellaneous.** · **ramp** – 3 m wide (min.) gravelled or paved ramp (or equivalent) from adjacent street or lane provided for emergency or maintenance access. Pathways or gravelled road to control structure provided for maintenance purposes if possible (2, 2)								
	· **pathway** – no signs or cracking or heaving (2, 2)								
	· final as-built construction drawings submitted in mylar material after a set of print drawings h[illegible] been checked and approved (N/A, 2/1)		✓						
11.	**Landscaping and Irrigation.** · inspection by Park Development & Operations to Landscape Construction Standard Specification & approved drawings (PDO, PDO)		✓				✓		
	· all vegetation & landscaping must be healthy (PDO/2, PDO/2)								
12.	**Maintenance Requirements.** · Maintenance period met for F.A.C. (N/A, 2)		✓						
13.	**Accounting Requirements.** · Copy of F.A.C. submitted to accounting (N/A, 1/,2)		✓						
	· telephone and utility accounts changed to WWD (N/A, 1)								

Contacts

Design & Datalogger: Stormwater Engineer[1]
Inspection: Sr. Inspector[2]
Electrical/Monitoring: Bonnybrook[3]

Designations:

(1/3,2)	C.C.C. Inspection done by group 1 and group 3, F.A.C. Inspection done by group 2 (groups are identified above)
PDO	Park Development & Operations
SP	Approved service provider for monitoring system
N/A	Not applicable

WET POND INSPECTION CHECK SHEET (July 2000)

Subdivision/Phase: ______________________ C.C.C. Issue Date: __________
Developer/Consultant: ______________________ F.A.C. Issue Date: __________

Item	Description	C.C.C.				F.A.C.			
		Acc.	N/A	Init	Date	Acc.	N/A	Init	Date
1.	**Grading.** · as-built cross sections of final grade submitted $^{(1,N/A)}$						✓		
	· side slopes (see requirements) $^{(1/2, N/A)}$						✓		
	· design volume $^{(1,N/A)}$						✓		
	· no signs of erosion around the pond $^{(2, 2)}$								
	· overland escape route/spillway as per construction drawing. Spillway in proper location at proper elevation $^{(1/2,N/A)}$						✓		
	· sediment forebay(s) properly constructed $^{(1/2, N/A)}$						✓		
2.	**Inlet/Outlet Structure. (to be checked prior to water being introduced)** · invert of grating(s) if required $^{(1/2, N/A)}$						✓		
	· invert of incoming/outgoing pipe $^{(1/2, N/A)}$						✓		
	· gratings bolted down or secured if required $^{(2, 2)}$								
	· no signs of erosion $^{(2, 2)}$								
	· little or no build-up of silt or debris $^{(2, 2)}$								
	· no damage (cracking, honeycombing, spalling) $^{(2, 2)}$								
3.	**Control Structure.** · rim and invert elevations $^{(1, N/A)}$						✓		
	· little or no build-up of silt or debris $^{(2, 2)}$								
	· no damage to structure (cracking, honeycombing, spalling) $^{(2, 2)}$								
	· **gate valve** - valve works properly (easily engaged) $^{(2, 2)}$								
	- valve face seals properly $^{(2, 2)}$								
	- automatic control gate(s) setup & working properly where applicable $^{(SP, SP)}$								
	· **trash rack** - trash rack removable and easily cleaned $^{(2, 2)}$								
	- trash rack free of debris $^{(2, 2)}$								
	· **weir wall** - elevation of top of weir wall $^{(1/2, N/A)}$						✓		
	- size of opening $^{(1/2, N/A)}$						✓		
	· **orifice** - centerline or invert elevation $^{(1, N/A)}$						✓		
	- dimensions of orifice (slot size, diameter) $^{(1/2, N/A)}$						✓		
	- orifice plate fits snugly to wall to minimize leakage around the plate $^{(2, 2)}$								

Item	Description	C.C.C.				F.A.C.			
		Acc.	N/A	Init	Date	Acc.	N/A	Init	Date
4.	**Storm Pipe System.** · invert elevations (1/2, N/A)						✓		
	· upstream piping fitted with rubber gasket (1/2,N/A)						✓		
	· storm manholes designed with bolt-down covers properly installed (2, N/A)						✓		
	· free of silt and debris (2, 2)								
5.	**Sanitary Pipe System.** · no sanitary sewer manholes are permitted within the pond (2, N/A)						✓		
6.	**Monitoring System.** · all level/alarm sensors are easily and safely accessible (3, 3)								
	· all sensors/alarms installed at proper elevations (1/3, 1/3)								
	· approved service provider must ensure: – alarm conditions ring through to E.E.C.C. at Manchester. Requires alarm sensors programmed to alarm at specified elevations. A calibration certificate is required and a schematic of the inside of the structure from service provider (1/SP, 1/SP)								
	· doors on electrical control box close/seal properly (3, 3)								
	· electrical control box in good condition. No signs of rusting or damage (3, 3)								
	· landscaping slopes away from electrical control box (2/3, 2/3)								
	· all conduit into electrical control box sealed to prevent infiltration of water and/or humidity (3, 3)								
	· all electrical equipment (fans, heaters) works properly and has been properly installed (3, 3)								
	· electrical control box with WWD "construction" lock (2/3, 2/3)								
	· Stormwater Engineer (WWD) to check datalogger: · datalogger recording properly. Phone number(s) supplied (1, 1)								
7.	**Signs.** · approved signs placed at entrances to ponds. No damage to signs (2, 2)								
8.	**Miscellaneous.** · **ramp** – 3 m wide (min.) gravelled or paved ramp (or equivalent) from adjacent street or lane provided for emergency or maintenance access. Pathways or gravelled road to control structure provided for maintenance purposes if possible (2, 2)								
	· **pathway** – no signs or cracking or heaving (2, 2)								
	· final as-built construction drawings submitted in mylar material after a set of print drawings has been checked and approved (N/A, 2/1)		✓						
9.	**Landscaping.** · inspection by Park Development & Operations to Landscape Construction Standard Specification & approved drawings (PDO, PDO)		✓				✓		
	· all vegetation & landscaping must be healthy (PDO/2, PDO/2)								

Item	Description	C.C.C.				F.A.C.			
		Acc.	N/A	Init	Date	Acc.	N/A	Init	Date
10.	**Maintenance Requirements.** · maintenance period met for F.A.C. (N/A, 2)		✓						
11.	**Accounting Requirements.** · Copy of F.A.C. submitted to accounting (N/A, 1/2) · Telephone & utility accounts changed to WWD (N/A, 1)		✓						

Contacts

Design & Datalogger:	Stormwater Engineer[1]
Inspection:	Sr. Inspector[2]
Electrical/Monitoring:	Bonnybrook[3]

Designations:

(1/3,2)	C.C.C. Inspection done by group 1 and group 3, F.A.C. Inspection done by group 2 (groups are identified above)
PDO	Park Development & Operations
SP	Approved service provider for monitoring system
N/A	Not applicable

WETLAND POND INSPECTION CHECK SHEET (July 2000)

Subdivision/Phase: ______________________ C.C.C. Issue Date: __________
Developer/Consultant: ______________________ F.A.C. Issue Date: __________

Item	Description	C.C.C.				F.A.C.			
		Acc.	N/A	Init	Date	Acc.	N/A	Init	Date
1.	**Grading.** · as-built cross sections of final grade submitted (1,N/A)						✓		
	· side slopes (see requirements) (1, N/A)						✓		
	· bottom slopes (0.5 to 1.0%) (1,N/A)						✓		
	· design volume (1,N/A)								
	· no signs of erosion around the pond (2, 2)								
	· overland escape route/spillway as per construction drawing. Spillway in proper location at proper elevation (2, N/A)						✓		
	· sediment forebay(s) properly constructed (1/2, N/A)						✓		
2.	**Inlet/Outlet Structure. (To be checked prior to water being introduced)** · invert of grating(s) if required (1/2, N/A)						✓		
	· invert of incoming/outgoing pipe (1/2, N/A)								
	· gratings bolted down or secured if required (2, 2)								
	· no signs of erosion (2, 2)								
	· little or no build-up of silt or debris (2, 2)								
	· no damage (cracking, honeycombing, spalling) (2, 2)								
3.	**Control Structure.** · rim and invert elevations (1, N/A)						✓		
	· little or no build-up of silt or debris (2, 2)								
	· no damage to structure (cracking, honeycombing, spalling (2, 2)								
	· **gate valve** - valve works properly (easily engaged) (2, 2)								
	- valve face seals properly (2, 2)								
	- automatic control gate(s) setup and working properly where applicable (SP, SP)								
	· **trash rack** - trash rack removable and easily cleaned (2, 2)								
	- trash rack free of debris (2, 2)								
	· **weir wall** - elevation of top of weir wall (1/2, N/A)						✓		
	- size of opening (1/2, N/A)						✓		
3.	· **orifice** - centerline or invert elevation (1, N/A)						✓		
	- dimensions of orifice (slot size, diameter) (1/2, N/A)						✓		
	- orifice plate fits snugly to wall to minimize leakage around the plate (2, 2)								
4.	**Storm Pipe System.** · invert elevations (1/2, N/A)						✓		

Item	Description	C.C.C.				F.A.C.			
		Acc.	N/A	Init	Date	Acc.	N/A	Init	Date
	· upstream piping fitted with rubber gasket $^{(1/2, N/A)}$						✓		
	· storm manholes designed with bolt-down covers properly installed $^{(2, N/A)}$						✓		
	· free of silt and debris $^{(2, 2)}$								
5.	**Sanitary Pipe System.** · no sanitary sewer manholes are permitted within the pond $^{(2, N/A)}$						✓		
6.	**Monitoring System.** · all level/alarm sensors are easily and safely accessible $^{(3, 3)}$								
	· all sensors/alarms installed at proper elevations $^{(3, 3)}$								
	· approved service provider must ensure: · alarm conditions ring through to E.E.C.C. at Manchester. Requires alarm sensors programmed to alarm at specified elevations. A calibration certificate is required and a schematic of the inside of the structure from service provider $^{(1/SP, 1/SP)}$								
	· doors on electrical control box close/seal properly $^{(3, 3)}$								
	· electrical control box in good condition. No signs of rusting or damage $^{(3, 3)}$								
	· landscaping slopes away from electrical control box $^{(2/3, 2/3)}$								
	· all conduit into electrical control box sealed to prevent infiltration of water and/or humidity $^{(3, 3)}$								
	· all electrical equipment (fans, heaters) works properly and has been properly installed $^{(3, 3)}$								
	· electrical control box with WWD "construction" lock $^{(2/3, 2/3)}$								
	· Stormwater Engineer (WWD) to check datalogger: · datalogger recording properly. Phone number(s) supplied $^{(1, 1)}$								
7.	**Signs.** · approved signs placed at entrances to ponds . No damage to signs. $^{(2, 2)}$								
8.	**Miscellaneous.** · **ramp** – 3 m wide (min.) gravelled or paved ramp (or equivalent) from adjacent street or lane provided for emergency or maintenance access. Pathways or gravelled road to control structure provided for maintenance purposes if possible $^{(2, 2)}$								
	· **pathway** – no signs or cracking or heaving $^{(2, 2)}$								
	· final as-built construction drawings submitted in mylar material after a set of print drawings has been checked and approved $^{(N/A, 2/1)}$		✓						
9.	**Landscaping.** · inspection by Park Development & Operations to landscape Construction Standard Specification $^{(PDO,PDO)}$								

Item	Description	C.C.C.				F.A.C.			
		Acc.	N/A	Init	Date	Acc.	N/A	Init	Date
	· all vegetation & landscaping must be healthy (PDO/2, PDO/2)								
10.	**Maintenance Requirements.** · maintenance period met for F.A.C. (N/A,2)		✓						
11.	**Accounting Requirements.** · copy of F.A.C. submitted to accounting (N/A,2)		✓						
	· telephone & utility accounts changed to WWD (N/A, 1)								

Contacts

Design & Datalogger:	Stormwater Engineer[1]
Inspection:	Sr. Inspector[2]
Electrical/Monitoring:	Bonnybrook[3]

Designations:

(1/3,2)	C.C.C. Inspection done by group 1 and group 3, F.A.C. Inspection done by group 2 (groups are identified above)
PDO	Park Development & Operations
SP	Approved service provider for monitoring system
N/A	Not applicable

Checklist for Electrical Inspection by Bonnybrook Inspectors (July 2000)

Subdivision/Phase: ____________________________________ C.C.C. Issue Date: __________
Developer/Consultant: ____________________________________ F.A.C. Issue Date: __________

Item	Description	C.C.C.				F.A.C.			
		Acc.	N/A	Init	Date	Acc.	N/A	Init	Date
1.	**Monitoring System.** · all level/alarm sensors are easily and safely accessible								
	· all sensors/alarms installed at proper elevations								
	· doors on electrical control box close/seal properly								
	· electrical control box in good condition. No signs of rusting or damage								
	· landscaping slopes away from electrical control box								
	· all conduit into electrical control box sealed to prevent infiltration of water and/or humidity								
	· all electrical equipment (fans, heater) works properly and has been properly installed.								
	· electrical control box locked with Wastewater & Drainage "construction" lock								

Contacts

Design: Stormwater Engineer[1]

Electrical/Monitoring: Bonnybrook[3]

Comments

____

____

____

____

____

____

____

____

____